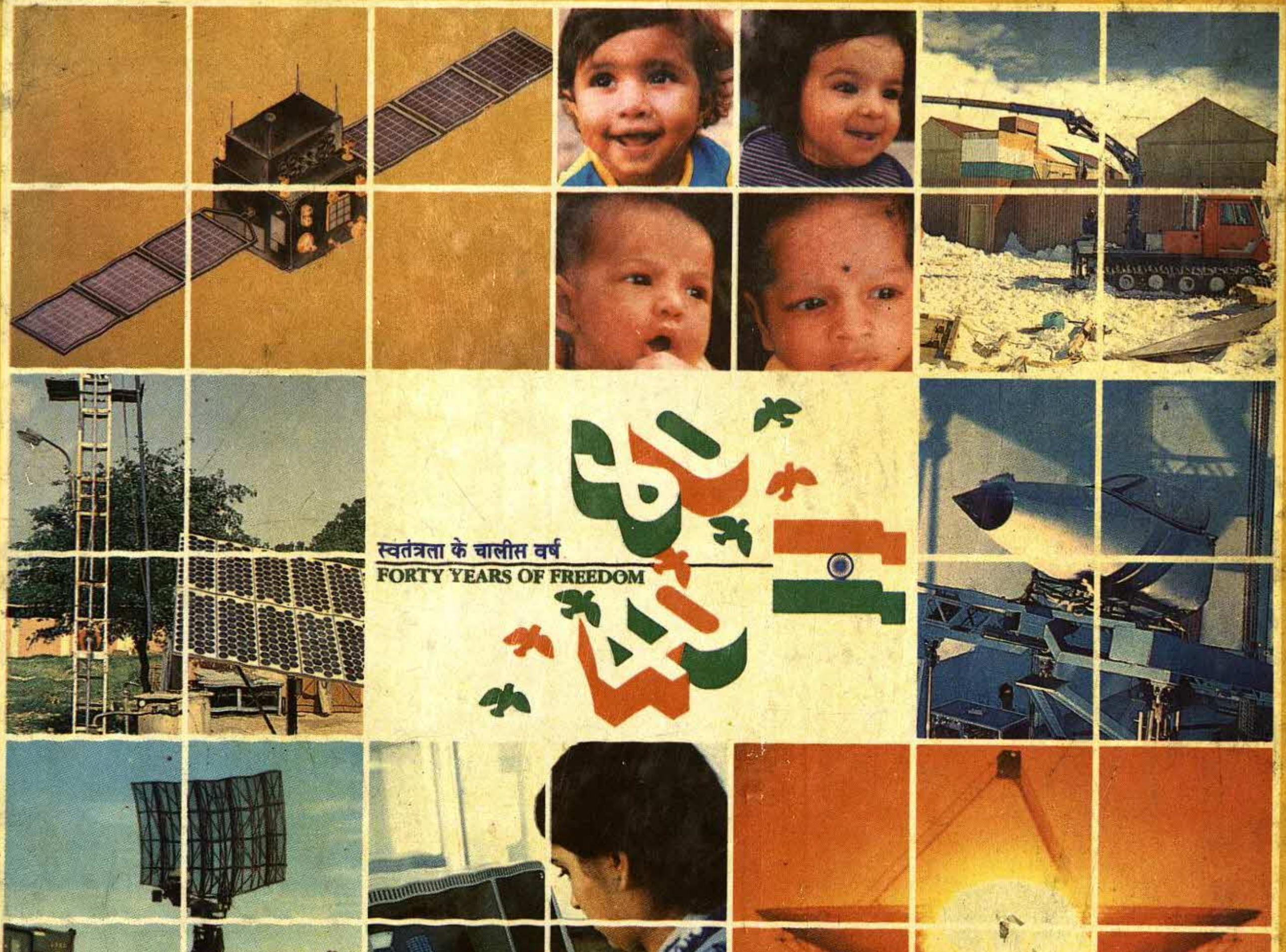
GLIMPSES OF INDIAN TECHNOLOGY

A SURVEY OF FOUR DECADES



BAL KRISHNA & Dr. C.P. THAKUR

With a Foreword by President R. Venkataraman

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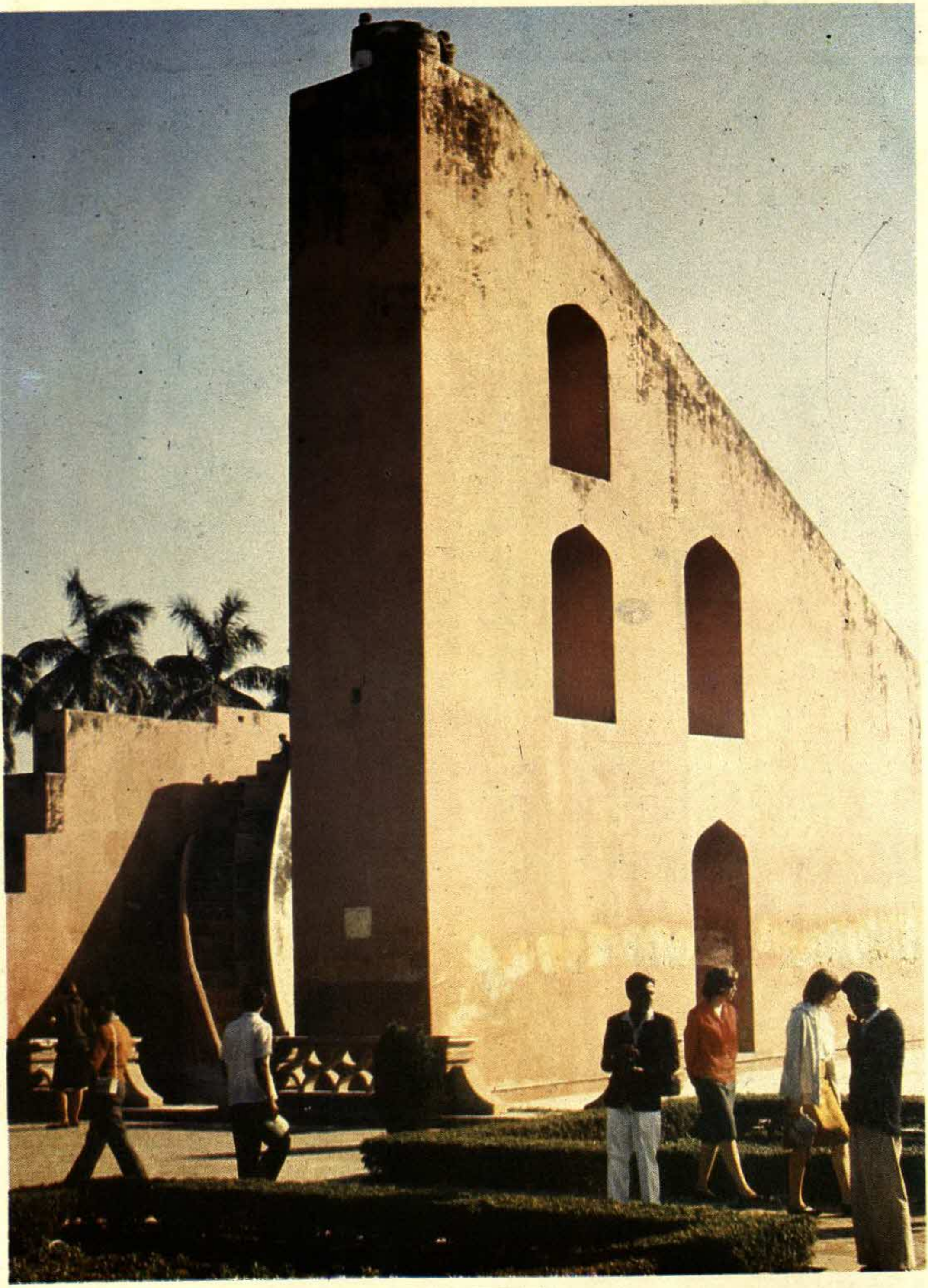

Jantar Mantar, New Delhi

Glimpses of Indian Technology
A Survey of Four Decades

With a Foreword by President R. Venkataraman

This Book to Commemorate the 40th Anniversary of India's Independence

Glimpses of Indian Technology
A Survey of Four Decades

Bal Krishna
&
Dr. C.P. Thakur

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Dedicated
to the Memory of
INDIRA GANDHI

सत्यमेव जयते
राष्ट्रपति
भारत गणतंत्र
PRESIDENT
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FOREWORD

Shri Bal Krishna and Dr. C.P. Thakur have rendered a useful service to lay-understanding of India's achievements in the field of Science and Technology through their book **Glimpses of Indian Technology--A Survey of Four Decades**. The general public is aware of the significant progress achieved in the realm of Science and Technology, but this awareness is limited to an appreciation of the more visible aspects of this progress. A great deal has, however, been done which is not conspicuous, but nonetheless, is very important. This book seeks to give a connected account of the multifaceted progress achieved. It describes, of course, our accomplishments in the realm of Atomic Energy, Space Science and Agriculture. It also fills in the details of the work of the Indian scientists and technologists in the realms of Biotechnology, Defence and Aeronautics, Lasers, Electronics and Instrumentation, Telecommunications and Non-Conventional Energy. A significant achievement of the book is to invest the narration with a sense of robust optimism and confidence in our future. It describes the evolution of what Nehru wished for, namely, the "Scientific Temper" in the country. I hope this book will inspire confidence in the decision-makers in Government and the entrepreneurs in Industry of the capabilities of Indian science. As the Seventh Plan Document points out:

> "There is often a feeling that the fruits of science and technology are not reaching the bulk of the population, and not contributing in sufficient measure to economic and social growth. For science and technology to be effectively applied, there is need to complete the total innovation chain consisting of basic research, applied research, design and development, prototype fabrication, upscaling, extension, design and consultancy, and production and service."

I trust this book will make a tangible contribution to this process.

The authors rightly conclude that given the will to pursue Research and Development work in various fields, India can achieve a self reliant economy. This optimistic note is certainly justified when one looks back on the progress we have made in more sophisticated areas like space technology, ocean bed explorations and Antarctica expeditions.

The book is written in a simple and lucid style without compromising on professionalism. It is bound to generate interest and also prove instructive to a cross-section of readers. I commend the effort of the authors and wish the publication every success and usefulness.

New Delhi
September 12, 1987

R. Venkataraman
(R.VENKATARAMAN)

Introduction

THE IMPORTANCE attached to technological innovation in the industrialised world will be obvious from the following statement of Sir Francis Bacon:

"It would be an unsound fancy and self-contradictory to expect that things which have never yet been done can be done except by methods which have never been tried."

Jawaharlal Nehru often referred to the paradox of a rich country inhabited by poor and starving people and asked: "Why are we unable to convert our natural endowments into wealth meaningful to our people?"

While naming our first swimming pool reactor, "Apsara", Jawaharlal Nehru reminded the audience that the Elephanta Caves on the other side of Trombay represent the spiritual roots of India and wanted that the power of science and the power of spirituality should become blended in the service of humankind.

Indira Gandhi portrayed the same idea in a different manner when she released a special stamp in 1968 to commemorate the beginning of the wheat revolution in the country. She said: "God was working alone in our fields for centuries. Men and God started working together with the evolution of agriculture over 10,000 years ago. Now, God, men and scientists have combined to produce two ears of wheat where only one grew before."

Thus, our political leaders have continuously underlined the fact that science and technology are the most important components of the dividing wall between poverty and prosperity. This condition has been reflected in the enormous support extended to scientists and technologists during the last 40 years. Few developing countries have extended similar support to S &T institutions. We owe a deep debt of gratitude to Shri Bal Krishna and Dr. C.P. Thakur for chronicling one of the most exciting adventures in human history in the development of the infrastructure essential for rapid technological advance.

Bal Krishna and Thakur have described in a lucid and systematic manner the progress we have made in every major sphere of science and technology since independence. They have drawn attention to the public policy support that has underpinned our progress, including the Scientific Policy Resolution of 1958 and the Technology Policy Statement of 1983. These resolutions represent a vision and provide a sense of direction for all scientists and technologists in terms of goals and objectives.

The authors have not only captured the essence of the evolutionary steps involved in the technological transformation of India but have also brought out our strengths and weaknesses in different fields of technology. The 40 years' balance sheet drawn up by them will provide a useful starting point to measure future advances and policy decisions. We owe Shri Bal Krishna and Dr. C.P. Thakur a deep debt of gratitude for their labour of love in the cause of India's technological progress.

DR. M.S. SWAMINATHAN
Director General,
International Rice Research Institute
and
President
International Union for the
Conservation of Nature and
Natural Resources

Manila, Philippines
August 25, 1987

Preface

TECHNOLOGICAL ADVANCES in India have been much greater in the past 40 years than in the previous 2,000 years. Despite this, most people in the country remain technically illiterate. Their lack of understanding prevents them from making informed decisions, and leaves the direction of technological advance largely in the hands of the technocrats themselves. Most people are to some degree aware of the pace of technical development. They occasionally notice introduction of the new techniques, inventions, and materials. But, what goes on in India's research laboratories largely remains a closed book. The society at large has remained uninformed and consequently unresponsive to these developments. This absence of interaction between the scientific community and the rest of the society inheres the danger of research being misdirected resulting in a sub-optimal use of the investment made.

The aim of this book is to enable the reader to understand and appreciate the latest Indian technological advances and to provide a clear and thorough survey of the numerous ways in which technology has shaped and is reshaping the country we live in. Recent advances in such fields as nuclear energy, biotechnology, health, lasers, electronics and instrumentation, oceanography, solar energy, agriculture, mining, rural technology and environment management and machine tools and robotics are described. New man-made materials, military and space technology, advances in the field of communication and aeronautics—all these are also covered. An effort has been made to study the Indian developments in a historical perspective and to provide a view of the contributions of Indian science and technology to the world of science during ancient and colonial periods.

As a result of these advances, a subsistence agriculture has been transformed into commercial agriculture, though gaps in the transfer of available knowledge to the fields are apparent. On the health front, a number of serious epidemics like plague and small pox, which used to take a heavy toll of population in the pre-independence days, have been eradicated. Although India has embarked on developing immunological approaches to contraception, communicable diseases like malaria, leprosy, filariasis and diarrhoea are still on the research agenda.

In the field of nuclear energy, capabilities have been established which span the entire nuclear cycle, namely, exploration, mining, extraction, purification, and conversion of nuclear materials, production of fuel elements for reactors, design and construction of power reactors, reprocessing of spent fuel and waste management. Capabilities have also been established in designing satellites and satellite launch vehicles, in providing telecommunications and remote-sensing facilities, and in dovetailing space research programmes to socio-economic problems.

In electronics and telecommunications, the book highlights capabilities that have been established in professional electronics equipment and systems required in defence, atomic energy, space research, communications and civil aviation. It also highlights two landmarks of the Department of Ocean Development—successful expeditions to Antarctica, including setting up of a permanent research station at Dakshin Gangotri, and the exploration of polymetallic nodules in the Indian Ocean and their commercial exploitation.

The book also deals with research being done in fields like immunology, particularly development of antipregnancy vaccines. It probes into efforts of Indian scientists in bringing the sun down to earth. The book also gives a brief account of more than 2,000 Indian technologies which are considered good for commercial exploitation.

We acknowledge with deep gratitude the inspiration given to us by the late Prime Minister Mrs Indira Gandhi to whom this book is dedicated. We also take this opportunity to express our sincere appreciation to President R. Venkataraman for providing a foreword. He encouraged us in every possible way to bring this publication to commemorate the 40th anniversary of our freedom.

This is perhaps the first effort of its kind and considering the fast pace of development and change in the world of science and technology, we propose to bring out updated editions at appropriate intervals. We would welcome advice and suggestions from readers for making future editions more interesting and useful. We hope this book would be useful, both in and outside the country, giving a glimpse of the scientific and technological developments in India.

BAL KRISHNA
DR. C.P. THAKUR

August 15, 1987
New Delhi

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They gave invaluable advice on the presentation of technical information comprehensible to a wide audience. Any oversimplifications or inaccuracies which remain are, of course, entirely our responsibility. Finally, we would like to express our gratitude to the Press Trust of India (PTI) for its continued support and various scientific institutions and departments for their continual encouragement and valuable comments on several drafts of the manuscript.

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History

INDIA'S MOST spectacular frontier is not only its great cultural and spiritual heritage but also the endless vision of science and technology which has been an integral part of the Indian tradition since time immemorial. While the people of Indus Valley Civilization made use of the wheel and possibly the plough, smelted and forged metal, and developed elaborate fire and flood controls for their farms and villages, today's scientists send rockets hurtling into the same skies mapped more than a thousand years ago by the first astronomers.

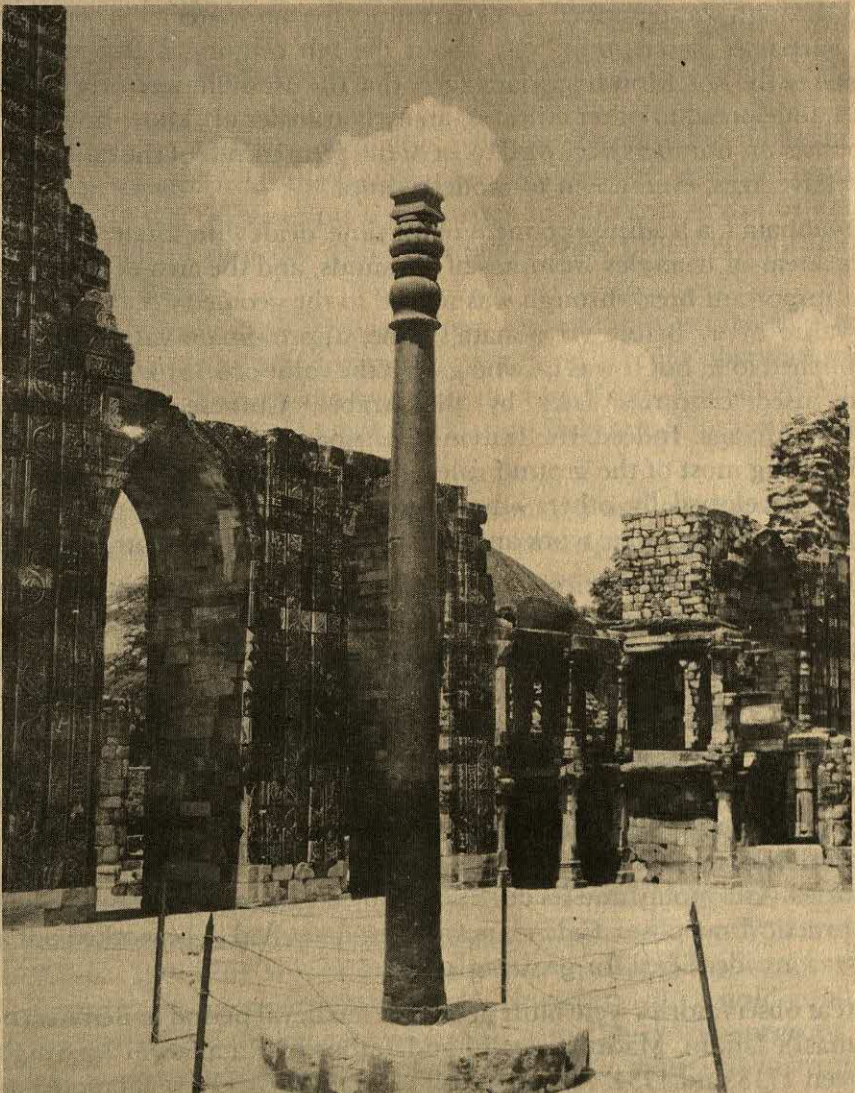
The first technological revolution took place in the country between 4000 B.C. and 3000 B.C. when India along with Egypt and West Asia emerged from the mists of antiquity. During this period, India was both technically and socially well advanced. Archaeological excavations have shown that there were then thriving cities and centres of commerce. The towns were well planned, the buildings were constructed of standardized fired bricks, and drainage systems were installed. Ports such as Lothal were developed as export centres for early manufactured products of smelted copper and bronze; polychromic paints were used to decorate pottery with a variety of animal and bird designs.

It was not until around 800 B.C. that the smelting of iron began and then, as today, it was the result of a technological spin-off from the primitive arms industry that existed at the time. In order to improve early weaponry, metallurgical experiments were performed which later led to the use of iron in agriculture and for other crafts. The proficiency of the ironsmiths still stands today in the form of the 24 ft. 3 in.-high, six-tonne iron pillar in Mehrauli, Delhi. It is made of wrought iron with an iron content of 99.72 per cent and appears to have been protected against rusting by the application of a thin coating of manganese oxide. A larger pillar, about 42 ft.-high, of a later period about 1200 A.D. now lies broken in several pieces at Char.

Harappa Montgomery mound parallel walls.

Several centres for iron founding and copper smelting and huge copper and brass images of the Buddha were frequently cast during the Classical Period from 400 A.D. to 800 A.D. According to an account by a Chinese pilgrim, one image of Buddha towered 80 ft. high. Buddha's and other statues were produced by the *cire perdue* (lost wax) process which is fully described in Sanskrit texts of the time. Construction engineers in the 12th century were using iron girders and beams on a scale unknown in any other part of the world. The most significant use is in the temples at Puri and Konark in Orissa. The Puri temple contains 239 iron beams, and one of the beams at Konark is 35 ft. long by about one foot square. All are 99.64 per cent iron and were produced in a similar manner as the Delhi iron pillar.

Religion played a vital role in the early days too. Some of the oldest recorded mathematical work such as "Sulva-Sutras" showed how geometry was used in the design and construction of altars. The early mathematicians of the 5th century, like Aryabhata and Bhaskara I, and later mathematicians



The Delhi iron pillar.

like Brahmagupta, Mahavira, and Bhaskara II, used and developed most mathematical formulas that we know today. A unique development followed in the 6th century the use of zero to represent a group of 1-9 digits or decimal place numeration. A symbol, in this case a dot, was inserted to represent the missing unit value (ten, hundred, thousand, etc.). This breakthrough was described by a 7th century Syrian writer as "a computing that surpasses description." By about the 9th century, a zero was used instead of the dot. Most historians agree that the use of the zero originated in India and spread to other cultures, an early transfer of "know-how." This emphasis on numbers occupied most of the great minds of the day through successive ages, even down to modern times.

Aryabhata I, a leading exponent of his time, dealt with square roots, cube roots, areas of triangles, volumes of pyramids, and the area of circles. The most important breakthrough was related to the geometry of the circle and the value of π. Before Aryabhata's time, approximate values had been established to π, but it was he who gave it the value of 3.1416, which was the value used centuries later by the Arabic, Chinese, and European mathematicians. Indeed, the Indian mathematicians were responsible for establishing most of the ground rules in use at the time and that were then further developed by others who followed. Bhaskara II is perhaps best known for his algebraic work and the compendium "Siddhartasiromani."

Allied with mathematics was the development and use of astronomy, whose earnest days were reported by Aryabhata and Varahmitra. Many later scientific works owe their origins to what are called the "Five Siddhantas", of which the "Surya" had a major influence on astronomical traditions in India. Aryabhata was the first to adopt a scientific approach to astronomy, establishing it as a separate discipline from mathematics. He also conceived the theory that the earth was a sphere rotating on its own axis. This and other contemporary radical ideas were the basis for the *Aryabhatiya,* an astronomical textbook, which was to have a wide influence for several centuries. Astronomy and its development were essential for both religious and practical purposes. Calendars and feast dates had to be worked out and the seasons identified for growing crops.

Great observatories were built in the late medieval period in Benares (now Varanasi), Ujjain, Mathura, Delhi and Jaipur by Raja Sewai Jai Singh II between 1718 and 1734. As lunar and solar calendars were tabulated, new instruments for measuring the stars and the planets were developed to add to the discussions on whether the earth was flat, spherical or revolving, but the geocentric concept continued to be the dominant one.

With the introduction of the astrolabe to India following Islamic influence, the instrument became the astronomer's most important aid. This led Lahore (now in Pakistan) to becoming an early scientific instrument-making centre in the 17th century. About 40 astrolabes of that period still exist today. Other instruments of the period included quadrants and armillary spheres.

The leading exponent of the age was undoubtedly Jai Singh, who produced an elaborate set of astronomical tables, the "Zij Mohammad Shahi," which were based on extensive research and astronomical knowledge not spread just in India but also in other parts of the world from China to Europe.

The enormity of interest in mathematics, astronomy, and medicine can perhaps be gauged from the fact that between the 12th and 18th centuries more than 10,000 manuscripts were written in Sanskrit, Arabic or Persian on these or allied subjects. Still more works were produced in the other languages of India.

There were many early science writers who not only produced original works but also wrote reputed commentaries on foreign observation and translated them. Two of the best known were Ustad Ahmad Al-Mi'mar Lahori, builder of the Taj Mahal, and Lutufu'llah, one of his sons, who was known as "the geometer."

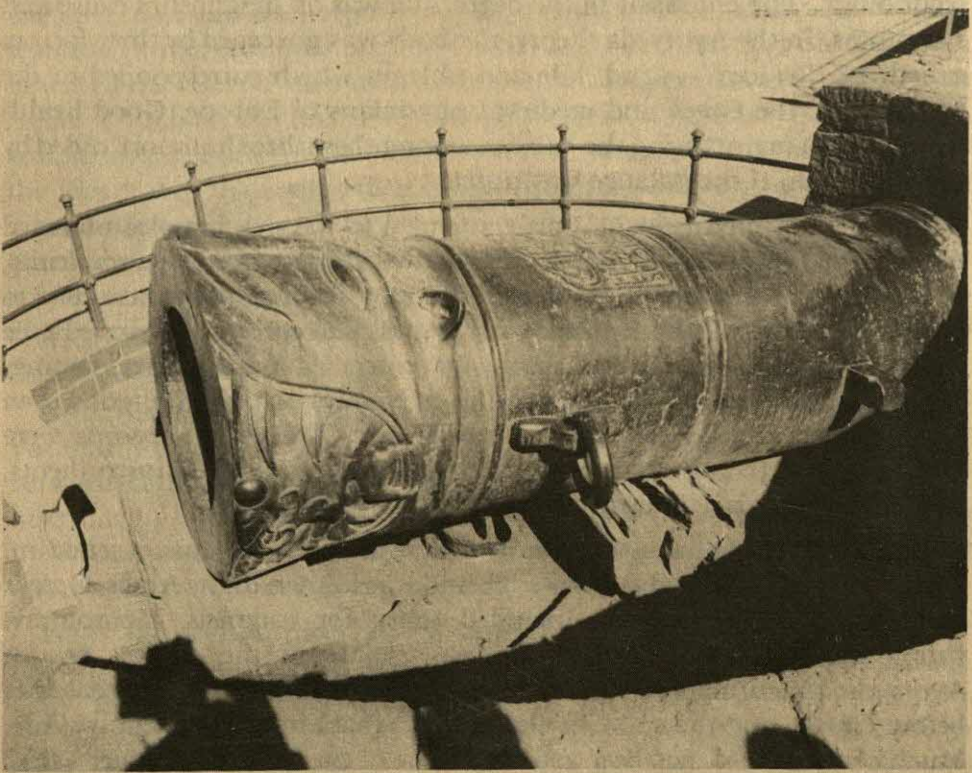
Parallel with the development of mathematics and astronomy were the advances being made in the medical field, principally the "Ayurveda," or "science of life," which included the development of dietetics and food technology. The emphasis in the beginning was on diagnostics cause and symptoms. In the Ayurveda theory, the body was governed by three factors called the "tridosa"—wind, bile and phlegm which corresponded to the humours of the Greek and medieval physicians of Europe. Good health depended on maintaining the balance among these three humours, aided by the physician, if the balance was upset.

The ancient physicians not only attended to the sick but also observed nature as a whole in the search for curative powers from flowers, fruits, seeds, leaves and minerals. Although the physician-philosophers had to have an immense breadth of knowledge and perception of Ayurveda, he would also specialize in one particular aspect. Good hygiene, nursing, drugs, and acceptance of the physician principles, which hold good even today, were essential elements of health care. The early surgeons were masters of their craft too, and developed more than 120 instruments, including scalpels, catheters, syringes and forceps.

Surgical expertise was something which the early Hindus excelled in. Their knowledge spread far and wide and was known to the Arabs, Greeks and Egyptians. Operations included those for cataracts, laparotomy, lithotomy, trepanning and rhinoplasty. Some of the earliest known Ayurvedic practitioners were Charaka and Sushruta in the early centuries before Christ, and the eminent clinician Vaghata in the 6th century A.D. Much of their work has been recorded. One of the best known later works available today is the treatise on the human eye by Zarrin Dut (1087-88), which identified visible ailments and those which could not be seen, suggesting prophylactic treatments for the latter. A little later, the invading Persians brought an important Islamic influence to bear on medical knowledge of the time. Continued research and exploration went into finding and using new drugs for both prevention and cure. This often acted as a catalyst for development and progress in alchemy and chemistry, which was often meticulously recorded. There is a wealth of ancient manuscripts, many of them written on dried palm leaves.

Because of the climatic conditions of the subcontinent, efforts were continuously being put into developing new methods of food preservation such as chutneys, murabbas, and the use of sherbet. From the earliest known days, great importance was always attached to hygiene and sanitation and the diseases which might result if proper standards were not observed. Studies were also made of plant genetics and diseases such as those recorded in works like "Vrksayuveda" published in the late 15th or 16th century.

The development of chemistry, apart from its use in producing drugs for the physicians such as compounds of mercury, arsenic, and herbal extracts, also



The gun at Maliki-e-Maidan.

led to applied technological processes in dye, paper, perfume, pyrotechnics, and sugar production. Allied with this development were the experiments in the use of new minerals, ores and mixtures of copper, iron, tin, gold, silver, and lead.

It was war and the need for better weapons that led to a comparatively rapid development of the armaments industry and the use of bronze, iron and steel for cannon-making from 16th century onwards. A couple of centuries earlier, the custom of coating copper cooking vessels with tin had been introduced. A special alloy ware, Bidari, was formed, and the extraction and use of zinc were developed; none of these were known in Europe until many years later.

Industrial technology reached its highest peak during the 16th and 17th centuries with the manufacture of cannons and hand guns of all kinds. These achieved considerable mechanical sophistication as well as aesthetic appeal. The 17th century hand guns had flint locks, and cannon barrels were made by rolling and twisting flat iron with heat edge welding, so that they could be bored from inside. Artillery techniques began to find varied applications with the introduction of bamboo shafted iron rockets.

During the 16th century, the armourers were producing cannons of immense size in bronze and iron. The Great Gun of Agra, in brass, weighed over 53 tonnes and the even bigger Maliki-maidan at Bijapur had a bronze barrel 14 ft. 3 in. long with a diameter of 4 ft. 10 in. at the mouth—the largest in the world at the time.

Religion, mathematics and agriculture were the dominant factors in everyday life from the earliest recorded days. Agriculture was to a large extent governed by the season. The need to measure rainfall and predict possible weather changes were as important then as monsoon warnings are today. Calendars for crop sowing and rain gauges were evolved; proper farming practices were established and various implements for tilling the soil developed. Like the physician-astrologer, the blacksmith and carpenter also assumed important roles in the life of the village. Heavier plough shares of up to 2 kg. in weight enabled deeper turning of the soil to be done and iron continued to be the supreme material right up to the introduction of British rule in the 19th century.

However, India's progress in the technological field is no less glorifying than that of science. In ancient period, the spectrum of technological development ranged from the progress of agricultural techniques to techniques of equipment that include sophisticated art of crafts and industries. Some of these age-old techniques are still in practice.

Coming to the agricultural scenario, except for a new tribes which practised cultivation on patches of burned land, the Indians since antiquity have been cultivating barley and numerous other types of grain, such as raggee (ragi, or African millet—*Eleusine coracana*), all kinds of peas and beans in the upper regions, and rice in the lowlands. Ploughing has always been done with very light wooden ploughes with pointed wooden (frequently iron, in modern times) plow-shares, that lightly scratch the muddy earth in the rice paddy. The plough is pulled by oxen or buffaloes. It lacks any device that would permit it to be rolled along the roads, but it is sufficiently light to be carried on the workman's shoulder. Plough, or working the land with instruments that turn the soil, buries the stubble left by the preceding harvest (or, in the case of fields that have been burned prior to this superficial turning of the earth, the ashes left by the fire).

The flooded rice paddies, which are separated by earthen dikes, are spread with fertilizers, cowdung (if the total available supply is not used as fuel for cooking) and especially the green foliage of certain trees (nowadays it is the foliage of the "bendy tree" or Portia tree—*Thespesia populnea*), which are left to rot in the water. Once the rice seed has sprung up in the starting beds, the shoots are pulled up and replanted in the rice paddies. The mature, harvested rice is thrown on open spaces and trampled by oxen and buffaloes to break open the ears. It is then gathered up and beaten on the ground to force out the grains. Lastly it is winnowed and spread out to dry in the sunshine. The husking and pounding of the grains is done in a narrow mortar with a long wooden pounder, which is grasped by the middle and used in vertical position. Pounding is also done with a piece of wood attached to the long end of a balanced beam; the beam is operated from the opposite (short) end.

The principal crops, in ancient as in modern times, are spices, oil-yielding crops, bananas, mangoes, jack-fruit, sugarcane, coconut palms, Palmyra palms, Areca palms, betel, the kapok tree, cotton, and jute in addition to the edible elements of its fruit, the coconut palm has always supplied fibrous elements for the making of rope and (like the Palmyra palm and several other species) the sap of its spathe for the production of a palm wine called "Toop" in the north, kallu in the south. Betel, a climbing plant cultivated for its leaves, which are chewed with lime and the betel-nut, has always been grown on stakes in carefully enclosed gardens. Sugarcane, like cotton, has always been essentially an Indian product. The Greek name for sugar, sakcharon, is derived from a popular form, sakkard, from the Sanskrit name carkara, which was specifically applied to coarse sugar. In addition to this product and sugar candy, the most rudimentary techniques of extraction supply brown molasses, which continue to be prepared and used. The device used for crushing oil-yielding fruits has for centuries been and in some places continues to be an animal drawn mill.

The raising of bovine animals in the country dates from a very remote period and continues to be of the greatest importance. Its purpose is to supply draft animals for agriculture and transportation and to supplement the food supply with dairy produce. Protected by a custom that is utilitarian as well as religious, the bovines, especially the cows and the zebus, were never killed to supply food for the people and their general protection for the purposes of dairy products and the requirements of agriculture is confirmed in the Constitution of India. No special techniques are practised in cattle raising; the animals are simply led in large herds to uncultivated lands. But the techniques of preparing dairy products have developed along lines that are very characteristic of the entire Indian world. In most cases the milk collected is not used in its original form, but is turned into curds, whey, and butter. The preparation of butter involves a special technique. The curdled milk is churned in a vertical churan rotated in a vessel by means of a rope wound around its middle and pulled first in one direction and then in the other. The butter collected is immediately melted, then chilled and decanted. It now has the consistency of light oil, and is called "ghee." The raising of sheep, pigs, chicken, and ducks has not given rise to any special techniques. Sheep rearing supplies wool for weaving, and leather.

Seagoing fishermen used hollow boats made of planks sewn together with coconut fibres—a construction that gives the hull the flexibility necessary for the passage of sandbars. Rafts made from trunks of trees lashed together are also used. The active devices used in fishing include many varieties of pots and nets. One technique of collective fishing, in use along the seacoasts, consists of stretching a huge net between several rafts and drawing it slowly into shore. Techniques of hunting utilize the bow, sling and the pike, depending on the animals being hunted; they are complemented by techniques of trapping, especially among the hunters of fowl. Animals, birds, and reptiles must be transported live to the markets, since dead creatures would immediately begin to decay in the tropical and subtropical climate.

The techniques of food preparation utilize a mortar for grinding grain. The mortar has a hemispherical cup in which is fixed a hemispherical stone capped with a short cone; the cone serves for the rotation (by hand) of the stone. Spices are crushed by rolling a stone cylinder over a stone platform; this device has frequently been found in archaeological excavation. Vegetables are cut with a concave knife set vertically in a piece of wood resting on the ground and held with the foot; the vegetables are pushed against the blade of the knife. Cooking is done on crude stoves over a fire of wood, charcoal, leaves, or dried cowdung. The most commonly used utensils are made of clay and consist mainly of jars and bowls (the jars are often made of copper also. For pots, large leaves are sewn together and arranged in the form of plates; large pieces of banana leaves or metal, mainly copper). Spoons are made from wood or the crown of a coconut. After the hands and mouth have been washed, the meal is eaten with the fingers of the right hand.

In the construction field, the earliest archaeological sites studied, at Harappa and Mohenjo-Daro in the Indus Valley, reveal the existence of an extraordinary technique of construction and layout of cities during the period from the middle of the third to the middle of the second millennium B.C. The cities of the Indus Valley Civilization (which, however, is now known to have extended into Gujarat) reveal a symmetrical arrangement of streets bordered by brick house. These cities are remarkable not only for their high ramparts, as at Harappa, but still more for a system of sewers placed under the streets and connected to pipes leading from the bathrooms of the houses.

In the later Vedic Civilization, in contrast,information supplied by texts leads us to envisage a single very crude and fragile type of house consisting of a framework of posts topped by a thatched roof supported by rafters, with mats for walls and partitions. Bricks were used only for the construction of altars to the God of Fire and secondary hearths; stone had a very limited use as a subsidiary material.

In the still later "Brahman" period, the remains of buildings and monuments were built of bricks that were generally large (modern Indian bricks are smaller, being comparable to modern European bricks). No traces remain of the wooden houses and buildings, but their appearance is preserved in pictures on bas-reliefs and in the stone architecutre of many monuments, which imitates wooden architecture. In addition, in the northern regions, in Cambay and Kashmir, as well as in Nepal, wooden architecture still exists, with its complex frameworks, covered balconies, and pavilions with elaborate sculptures.

The art of cutting and building in stone has always been remarkably well developed, in contrast to the art of wood and brick construction. Remains of large stone walls mark the sites of fortresses or old palaces, as at Patna, the site of the former capital of the Maurya kings of the fourth and third centuries B.C. Many ancient sanctuaries of the west (regions of Kathiyawar, Bombay) eastern India (Orissa) and the south (Tamil Nadu) are artificial grottoes cut out of the rock, complete with columns and interior decoration.

The technique used in cutting these grottoes is clearly revealed by those that were left unfinished. A series of squares, marked out with a chisel on the rock walls, determined the direction of attack. The crudely hewn elements were gradually refined and polished, and finally elaborately sculptured. Certain temples, like those of Mamallapuram (Mahabalipuram) south of

Madras or Ellora, northeast of Bombay, are monoliths carved out of enormous blocks of rocks, like gigantic statues.

Temples, fortresses, large palaces, and Mughal tombs were built of stone—rose or red sandstone—in the north, in the regions of Delhi, Mathura, Agra, and Jaipur, or white marble, like the famous Taj Mahal of Agra, other sandstone in Orissa, granite in the south, with superstructures of brick in the case of very tall temples. The technique of construction used in building stone temples began with the complete construction on the ground, of the upper floors and top. Once the stones had been exactly fitted together, they are marked. Then the structure was dismantled and carried up piece-by-piece, by means of wooden ramps, to its proper place, where the stones were reassembled in accordance with the markings. This method of construction, which made it possible to do the greatest portion of the work conveniently on the ground, pre-figured the modern (called "anastylosis") that is used to reconstruct ruined monuments whose elements can be found and identified.

Stonecutting, like stone sculpture, remains common in regions that have quarries. Simple fences have often been built of stone, notably with enormous granite slabs crudely but evenly cut. The cutting of the blocks was (and still is) done by drilling small, closely spaced cubical holes along the line selected for breaking, thus decreasing the resistance along this line. Dry wooden cubes are forced into these holes and then wetted; their swelling causes the stone to break.

In the oldest constructions, like the sandstone walls around the monuments of Bharhut (Satna) and Sanchi and the marble walls of Amaravati, the stones were cut and fitted in imitation of wooden elements, vertical posts being dug laterally from mortises in which the horizontal stone crossbars were fixed.

Important buildings or parts of important buildings were stuccoed and painted. Stucco work was frequently used to cover stone sculptures, either as a base for coloured decorations or to increase the size of the original monuments or to modify its architectural design. Copper facings or even gilded tiles are frequently found above main sanctuaries of temples.

In marble monuments of the Mughal period, the encrustation of semi-precious stones or small mirrors decorates wall surfaces and makes them gleam. Part of these encrustations was the work of Italian and French artists working at the Mughal courts in the seventeenth century. Finely carved screens of sandstone or marble were often used to cover the openings in these monuments.

Ordinary houses were built of brick, and had an outer veranda and a central courtyard surrounded by a cloister with wooden columns. They were rooted with tile, and frequently had a roof of palm-tree leaves over the courtyard. The terraces and flooring of well-to-do homes were made of a hard and smooth cement. The flooring of poorer houses consisted of packed earth that was given a daily coating of cowdung blended with water. This formed a relatively smooth coating that eliminated dust and the slight surface irregularities propitious to the development of insects.

The house of the Indian farmer has always been built of low mud walls, with a roof of palm-tree leaves that extends quite close to the ground. There are also low round huts with walls of bamboo stalks encircled with fibre ropes and square dwellings with roofs supported on posts stuck into an earthen footing, the walls being made of bamboo screens or braided palm leaves.

Water was obtained with modern installations from pools, cisterns, and wells; major buildings had pipes. The removal of waste water was ensured by deep gutters and open sewers. The very numerous pools required for the continual baths of the population (the frequency of the use of the baths in India astonished medieval Chinese travellers) were dug, in most cases by human labour, to hold the water during the rainy season. The largest ones were bordered with stone steps. Irrigation was one of the most highly developed techniques in India, beginning with the ancient Indus Civilization. Major hydraulic projects are frequently mentioned in ancient royal inscriptions; they consisted chiefly of dikes built to create reservoirs, and irrigation canals.

The irrigation of the fields and rice paddies, when it was not done by means of canals or ditches, was accomplished by various devices. The water was drawn from the well in a waterskin on the end of a rod, which balanced around an axle located at about one-third of its length. A man standing on the shortest end of this arm alternately lowered and raised the skin; an assistant emptied it the side that was to be watered. Animals were also used for this chore, by means of a sloping embankment of earth against the well. Two oxen descending the slope pulled the waterskin out of the well by means of a rope that was attached to their yoke and passed over a pulley. When the animals walked backward up the bank, they caused the waterskin to plunge back into the well.

Another technique, used on the edge of a pond or a river, utilizes a rod that balances on a post planted on the bank. The long end of the rod extends out over the water; the other is weighed with a stone. A wooden trough is placed beneath the end of the rod that is resting on the riverbank; it is attached at the other end to the long part of the rod. A man standing in the water lowers this end, thereby plunging the gutter into the water, then lets it rise by the effect of the stone counterweight, which raises it and causes it to pour its water into a ditch on the bank.

Main roads were established at a very early period; they were planted with trees and had inns for travellers, as is indicated by the inscriptions of Asoka in the third century B.C. Cisterns built on piles and, more frequently, stone porches were located at regular intervals. These porches, as tall as a man, permitted travellers to put down and pick up the burdens they carried on their heads.

The public works employed a considerable labour force armed with picks and shallow baskets no more than nineteen to twenty-five inches in diameter; these baskets were used for carrying soil and materials in small quantities.

The traditional methods of transportation were the pack animals—elephants, donkeys, buffaloes, camels (in the north-west), and especially chariots and light carriages pulled by oxen, and palanquins carried by men. The vehicles generally had wheels with very large rims. The large chariots of gods used in processions in southern India and Orissa had large and sometimes numerous high wheels. These chariots carved out of wood were shaped like the bases of tower sanctuaries, and had a light wooden frame to hold the statues of gods; the frame was covered with canvases hanging curtains, and garlands of flowers. These chariots were pulled (by means of ropes) by a crowd of people and not by animals.

The rudimentary palanquin was a net bed suspended from a long wooden rod supported in front and in back by porters.

Small burdens were carried on the head, often on the hip (jugs and children) and, in the north-east, perhaps on both ends of a rod the centre of which was rested on the shoulder. This method of carrying burdens is widely used in the Indochinese peninsula and throughout the Far East.

At a very early period a well-developed craft tradition was already supplying all the tools needed by a society that was refined but little encumbered with furnishings. The traditional furniture of the Indian house consists especially of chests and beds. The bed is a wooden frame supported on four feet, on which a rope net is stretched. The net, which is made of parallel, closely woven strands whose tension can be varied, is more tautly stretched at the head of the bed; it is covered with a mat. Interwoven straps are sometimes used instead of a net. Swings made of heavy wooden platforms suspended on chains permit those who sit in them to enjoy a breeze by means of a slight push from a foot left to rest on the ground. The traditional lighting used the Indian homes was the oil lamp with a cotton wick, either alone or in groups that form a candelabra.

The various crafts that supply equipment have always been divided among closed communities that avoid intermarriage and even contact in daily life, especially during meals. These communities very often specialize in crafts which they have turned into local monopolies: carpentry, smithing, pottery making, leather-working, and so on. Techniques are handed down from father to son, orally and by example, within these groups, and thus are rarely set down in detailed manuals. Technical books are hardly more than books of formulas, especially in the cases of medicine and chemistry, and even these are only notes that presuppose a knowledge of the fundamental procedures.

Metallurgical techniques, of which we have no descriptions, nevertheless produced masterpieces at a very early date, such as very large columns of almost pure iron cast in a single block. The most remarkable specimen is the so-called "Delhi" Iron Pillar, which now stands near Qutub Minar in a suburb of New Delhi. It bears a Sanskrit inscription dating from the fourth century A.D.; it stands more than 23 feet high, is 16 inches in diameter at its base, 12 inches at its capital-crowned top, and weighs more than six tons. It was cast in a single piece, including the capital, without joints.

The techniques demonstrated by such monuments were not exceptional. Even before the fourth century they were being widely practised, along with those of bronze and tin, gold and silver, for Indian iron is mentioned as an item of trade in the first century by a Greek text, the Periplus of the Erythrean Sea. In the twelfth century these techniques were still producing remarkable results, as is indicated by the iron beams used in the construction of several temples in Orissa.

Until the beginning of the nineteenth century steel was obtained by case-hardening. Iron extracted from magnetic iron ore was heated in crucibles for four or five hours, together with dry wood shavings and the leaves of various plants over charcoal fires, fanned by bellows; it was then reheated to reduce the excess carbon, and sprinkled from time to time with water, whey, or liquid butter.

Copper, brass and bronze were employed in very large quantities. Bronze statues three feet tall and taller are very numerous, especially in the south. Small statues were produced in a great quantities. Metal encrusted on metal was specially produced by artists of various regions such as Hyderabad and Tanjore.

Artisanal chemistry, which was very well developed, not only permitted numerous alloy preparations, but was also very advanced in the treatment or use of various minerals, particularly mercury salts, together with organic vegetables, and animal products. All sorts of preparations resulted from the most varied drugs to the stucco and cement used in the construction and the production of various objects.

Included in the specialities of Indian technology are several very hard cements (vajralepa, "adamantine paste") obtained with lime and resins first extracted and blended for decoction, then reduced to liquid form by prolonged periods of distillation. It was cheifly on dry surfaces obtained by procedures of this type that mural painting was done. A glue prepared by prolonged boiling of buffalo skin, the product of which was reduced and preserved in dry sticks and diluted when needed, served the painter as an adhesive. The lacquer technique, including its name (laksha in Sanskrit, lakkha in the vernaculars), originated in India.

The most remarkable Indian techniques are undoubtedly those concerned with clothing. Others, such as faience, have been completely neglected. Indian dishes unlike their Chinese counterparts, were made of terra-cotta or metal, and were very simple affair. The development of highly perfected techniques of weaving and dyeing, especially for cotton, and the preparation of indigo dates from ancient times. As we mentioned earlier, the use of fabrics made from cotton was already known in India in antiquity. The weaving of wool, especially in Kashmir, and of silk in Kasi (Varanasi) is a traditional industry famous for the fine quality of its fabrics.

The typically Indian garments for women is the sari (a word that is of feminine gender in most of the languages of India, but neuter in the south), formed of a piece of cotton or silk cloth about six yards long, woven in a single piece, with a decorative pattern along the edges and one of the ends. This garment, which has neither seams, buttons, nor hooks (as is also true of men's garments), is rolled around the body, and its decorative end is thrown over the shoulder as a scarf or is used to cover the head. The Indian textile craft has been well developed in recent centuries, especially in the production of pieces of cotton fabric, generally checkered, which are used by the Moslems and are often exported to Malaysia, Indochina and Indonesia.

Aesthetic techniques include, in addition to those of the fine arts (sculpture, painting, metalworking, and various decorative techniques), goldsmithing and the working of precious stones on the one hand, music and dancing on the other.

The finding, cutting, and setting of precious and semiprecious stones is a very ancient Indian speciality. Pearl fishing, practised off the southern part of the eastern coast, is known to have been in existence since the end of the fourth century B.C. from the evidence given by Megasthenes, the ambassador of Seleucus Nicator to the court of King Chandragupta. Indian lapidaries, who unfortunately described the characters of the stones rather than techniques for their use, were numerous.

Semi-precious stones were principally used as inserts in marble, to form decorative floral motifs; this use can be seen in the Mughal monuments of Delhi, Agra, Fatehpuri Sikri, and elsewhere. These decorations are round side by side beautifully carved marble or sandstone screens; a great number of these screens have been preserved.

The making of jewels, bracelets, necklaces, ankle rings, pectorals, ear-rings, nose jewels, diadems, and forehead pendants, has always been a very busy industry. Personal ornaments are made not only for women but also for statues of the gods and human or zoomorphic figures. Breastplates of embossed silver have often been made for stone statues of the gods.

The reader might be surprised to see yoga included in a book that essentially deals with technology. But we believe that these traditional techniques of using physical exercises to boost health and fitness, pioneered in ancient India, should not go unnoticed. In India the sensation of physical and psychological comfort has always been sought less from artificial external means than from the exercise of personal discipline. Walking barefoot, sleeping on a hard surface, eating frugal meals are not misfortunes but skills. Thus habits acquired in childhood free the individual from his dependence on objects. Possible deprivation is less keenly felt, and techniques of luxury are less important.

In addition, the preparation of the craftsmen or artists for technical accomplishments very often rests upon a preparatory psychophysiological training determined by precise rules. The principal specific technique of the body is yoga which is aimed at most complete, possibly, mastery of the body and mind. Psychologically speaking yoga is based on fundamental regulation of breathing (*pranayama*) and on the assumption of stable postures (*asana*). When developed further, it may include the prolonged suspension of respiration, and achieve deliberate restriction of the movements of the heart, registered by the electrocardiogram and clinically demonstrated by the cesstion of the pulse and of the sounds of ausculation. In most cases it includes the assumption of complex postures, training in the isolated use of muscles that normally function as a group, and an action on the rectal and vesical cavities, which can then be contracted and expanded at will. This is called hatha-yoga.

Psychologically it consists of successive stages that include the neutralization of sensory stimulations (pratyahara), fixing of attention (dharna), meditation (dhyana), total fixation of psychic activity on a single idea (samadhi), and, in its ultimate stage, the maintenance of the psychic being through the extinction of this thought in a stable position where it remains itself, liberated from all sense reaction, whether affective or intellectual. This is the "royal yoga", or raja-yoga.

Since the physiological and psychological conditions of the exercise of yoga complement and benefit each other, it is always (though in varying proportions) both a psychotechnical and a corporeal gymnastics. When practised in any degree for a control of the physical and psychical individuality, it naturally serves as a preparatory discipline for the artist who wishes to utilize his skills to the maximum and who derives from it at least the benefits of an automatic concentration on his activity.

During the British period, emphasis on science and technology was directed towards meeting the needs and requirements of the then government by increasing trade, communications and defence. This resulted in several important advances such as the first scientific survey of the country, and a network of meteorological stations, the building of canals and the establishment of the railway system. Several academic institutions were created such as Asiatic Society in Calcutta in 1784, the Indian Association for the Advancement of Science founded in 1876 by Mahendra Lal Sircar, and many others. All these helped create a greater awareness of science in the country and eventually led to the birth of modern science in India between 1890 and 1940. However, the end of the last century and the first 50 years of the present one was a period of renaissance of science for India. During this time, some of its able scientists were produced. The earliest of great pioneers was Sir J.C. Bose (1858-1937) who demonstrated the production and detection of 5-25 mm electromagnetic waves. He later developed sensitive measuring instruments for monitoring plant growth and behaviour.

Perhaps the greatest discoverer of all was C.V. Raman, born in 1888. He was the son of a mathematics teacher. In 1928, Sir C.V. Raman, as the later bacame, discovered the "Raman Effect," the quantum theory of diffusion of light. He was awarded the Nobel Prize for his outstanding work. He was a man of considerable all-round ability; besides being a scientist of distinction, he was a musician and artist. He once remarked, "The history of science has shown that real fundamental progress is always due to those who had ignored the boundaries of science and who treated science as a whole." This could not have been more true than in his case. Most of his experiments were done in Calcutta and later in Bangalore where he established the Raman Research Institute. He died in 1970.

The development of mathematics and physics played a vital role during this renaissance period, a reflection on the great heritage of science in the country. Another example of this was the work of S.N. Bose, which led to the Bose-Einstein statistics. An outstanding astrophysicist was Prof. Meghnad Saha (1893-1956) known best for the Saha equation relating to stella spectra, his research into ionization, and the propagation of radio waves in the upper atmosphere. He was founder-director of the Institute of Nuclear Physics established in Calcutta in 1955 and a leader of modern astrophysics.

Srinivasa Ramanujan, who lived only for 33 years (1887-1920) was a mathematical prodigy of great originality and was largely self-taught. He was one of the first Indians to become a Fellow of the Royal Society in 1918. In more modern times, one person who was to have the greatest impact was Dr. Homi Bhabha, father of India's nuclear programme. He was a man of vision and campaigned ceaselessly for more resources for research. He was instrumental in establishing the Tata Institute of Fundamental Research, which was later incorporated into the Bhabha Atomic Research Centre. Born in 1909, his life ended tragically in an air crash in 1966, just two years before the opening of India's first nuclear power station.

India's space programme was first envisaged by Vikram Sarabhai (1919-1971), who studied cosmic ray effects under C.V. Raman. His later research led to the discovery of new solar relationship concerning cosmic ray variations.

Another Nobel Prize winner is Har Gobind Khorana, a biochemist who was born in 1922. He has won many awards for his medical research. His outstanding achievements include the production of artificial genes. He is now living and working in the United States, where he has held the Sloan Chair of Chemistry and Biology at the Massachusetts Institute of Technology since 1970.

Post Independence Era

However, it was only after independence and through the vision of Pandit Jawaharlal Nehru that science and technology were developed in a conscious way as a major force for accelerating social and economic change. In his *Discovery of India,* Nehru expressed his conviction in these words: "It was science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people." The enthusiastic efforts of Sir Shanti Swarup Bhatnagar led to the expansion of the Council of Scientific and Industrial Research into a chain of national laboratories spanning a wide spectrum of science, technology, engineering and biomedical sciences. The vision of Homi J. Bhabha led to advanced research in nuclear energy and other fundamental areas through the creation of the Tata Institute of Fundamental Research (TIFR) and what has now come to be known as the Bhabha Atomic Research Centre (BARC) and the entire gamut of activities today coming under the Atomic Energy Commission. The space programme envisioned by

Vikram Sarabhai in the seventies has grown into a self-confident and dynamic area of Indian science.

The Government of India adopted the Scientific Policy Resolution on March 4, 1958, with the following major objectives: "The key to national prosperity, apart from the spirit of the people, lies in the modern age in the effective combination of three factors: technology, raw materials and capital of which the first is perhaps the most important, since the creation and adoption of new scientific techniques can in fact make up for a deficiency in natural resources, and reduce the demands of capital." It indicated the government's intention to support science and technology in order to "secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge."

The goals of research and development evolved in the following phases: creation of infrastructure for research; promotion of research aimed at import substitution, export promotion and solving the economic problems of the country; attainment of self-reliance; science for the people; and promotion of basic research and international impact. The first phase of development of technology was the establishment of infrastructure for research. Five areas, namely, agriculture, atomic energy, space science and technology, industrial research and general science and technology, all financed by the government, accounted for 70-80% of the total expenditure on science and technology, which itself is about 0.7% of the gross national product.

Today, India's R&D infrastructure is made up of 130 specialized laboratories and institutions set up mainly under the aegis of the Indian Council of Agricultural Research (ICAR), the Council of Scientific and Industrial Research (CSIR), the Indian Council of Medical Research (ICMR), the Department of Atomic Energy (DAE), the Department of Science and Technology (DST), the Department of Environment (DOEN), the Department of Biotechnology (DOB) and the Defence Research and Development Organisation (DRDO). A chain of institutes of technology on the model of the Massachusetts Institute of Technology (MIT) of USA were created. The University Grants Commission (UGC) and the Ministry of Education provide major support for scientific and technological activities in the educational institutions. Over 900 in-house R&D units set up by various private and public sector undertakings largely meet their own needs. An important development has been the rapid growth of consultancy organizations providing engineering design, erection and consultancy services, which act as a bridge between R&D institutions and industry. About 20,000 scientists and technologists are employed in about 200 such organizations.

The policy of import substitution and export promotion was adopted in the late fifties and early sixties when India was faced with a severe crisis of foreign exchange shortage. This was possible by the positive response of the scientific community by reorientation of its research programmes. Sometime later, further development along these lines led to a well-defined policy of self-reliance. A clear-cut exposition of this policy was reflected in a document prepared by the National Committee on Science and Technology entitled Approach to Science and Technology Plan. It provided the basis for the formulation of the Fifth Five-Year Plan. It was during the Fifth Five-Year Plan that questions like 'science at what cost, for whom and for what purpose?' began to be asked. The debate yielded as a byproduct, a paper on 'Alternative Technology' embodying new thinking on the nature and character of science and technology and led to working out of new priorities. At the instance of the Prime Minister, the Indian Science Congress Association at Waltair was devoted to the theme of 'rural technology.'

The experience of using science and technology for rural development and for the uplift of the downtrodden brought to surface the fact that their solution required the most sophisticated science and technology. Further, in addition to finding technical solutions, they required to be integrated with social conditions and the economic constraints and supported by a proper delivery system. This manifested in the need for long-term and basic research interposing natural and social sciences.

Three new dimensions—the problem of safeguarding the environment, factors arising out of interaction of science and technology with society and the development of an information system and its use in decision-making—were incorporated into the science and technology policy. New agencies and departments were set up to undertake research in newer areas of technology like space research, mining of the sea and the exploration of Antarctica.

Another important landmark was the Technology Policy Statement of January 1983. The main aims of this policy are: to attain technological competence and self-reliance, to reduce vulnerability, particularly in strategic and critical areas, making the maximum use of indigenous resources; to provide maximum, gainful and satisfying employment to all strata of society, with emphasis on the employment of women and weaker sections of society; to use traditional skills and capabilities, making them commercially competitive; to develop technologies which are internationally competitive and have export potential; reduce demands on energy, specially from non-renewable sources; ensure harmony with the environment, preserve ecological balance and improve the quality of the habitat; and recycle waste material and make full utilization of byproducts. The overall emphasis is on food, health, energy and industry. The policy is very clear regarding the need to reduce the technological dependence in key areas. It also lays emphasis on: agriculture, including dry land farming, optimum use of water resources, increased production of pulses and oilseeds; provision of drinking water in rural areas, improvement of nutrition, rapid reduction in the incidence of blindness, eradication of major communicable diseases (such as leprosy and tuberculosis), population stabilization and low-cost housing.

As a result of this, major strides have been made in the development of a strong industrial base for the country, which has been supported by a policy of planned investment. Rapid progress has been made in the production of steel, non-ferrous metals, cement, paper, chemicals, fertilizers, as well as heavy engineering and manufactured goods. These include ship-building (India is among the world's top ten shipbuilders), the construction of offshore oil drilling platforms and equipment, locomotives, earth-moving machinery, tractors, buses, and other commercial vehicles. India has also developed its own technology for petrochemicals and plastics.

Significant changes have taken place in textile production, which is one of the oldest industries in the country. Traditional silks and cotton, which account for the major proportion of production, have now been augmented by many man-made fibres. But in order to generate greater economic activity in rural areas, there has been a major revival of the handloom weaving industry, which has about 10 million workers producing 3 billion metres of cloth a year. The mills, which have another 1 million workers, produce 7 billion metres of cloth a year.

Steel production from six major steel plants has increased from 3 million tonnes a year during pre-independence days to 10 million tonnes a year now providing the basis for a whole range of manufacturing industries. This has enabled a large degree of self-sufficiency to be achieved in certain production areas, such as manufacturing machinery for cement making, sugar refining, material handling, equipment, and the engineering industry in general. There has also been some progress in producing more consumer goods, many of which have good export potential.

The expansion of the industrial base of the country has meant a strengthening of the energy sector, particularly the supply and transmission of electricity to both rural and urban areas. Forty years ago only some 3,000 villages received electricity. Today the number has risen to 400,000. The main sources of electricity generation are hydro and coal-burning power stations. There is also a contribution from nuclear stations. The total installed generating capacity has increased from 2,300 MW in 1950 to approximately 50,000 MW now.

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Advances in Agriculture Sector

The production has risen from 50 million tonnes in 1950 to 150 million tonnes in the field of agriculture. The improvement in foodgrains production has been possible through sustained research efforts in the areas of high-yielding crop varieties and improvements in the production technology thereof. The following are some of the areas of technology generation in the agricultural sector:

(a) Gene Sanctuaries: Gene sanctuaries are established to preserve rare species in the natural habitat for use in crop improvement programmes. The Bureau of Plant Genetic Resources, set up in 1976, coordinates work on exploration and collection of germplasm and quarantine in collaboration with the International Plant Genetic Research Institute. Bureaus of fish and animal genetic resources are also being set up.

(b) Soil Productivity: The country has been divided into 186 land resource areas and a soil atlas for the country is in the offing. An inventory of soils in the country has been prepared; it also covers micro-nutrients which will be useful for scientific land use and conservation. Large areas of saline/alkaline soils have been reclaimed.

(c) Genetic Architecture: By repatterning genetic architecture, hybrid maize, dwarf wheat and hybrid cotton have been developed. Further development in triple-gene dwarfs in wheat, composite varieties of maize and long staple cotton have added both to production and productivity. These breakthroughs were not without support from plant protection research, breeding resistant varieties, chemical control and cultural methods.

(d) Mutation Technology: The emphasis in research in animal husbandry has been on selective breeding in some tracts of indigenous breeds and cross-breeding of non-descript cattle. These have resulted in improved strains like Karan Swis and Karan Fries in cattle, Avikal-in and Avivartra carpet wool strains of sheep and ILI-18 and IBL-18 strains for broiler and egg-layers in poultry. The breeds of buffaloes have been improved by perfecting semen preservation technology.

(e) Animal Health: The major achievements in this area have been increased use of tissue culture, vaccine against foot and mouth disease of cattle, goat disease vaccine for rinderpest, oil-adjuvant vaccine for haemorrhagic septicaemia of buffaloes. Vaccines have also been developed for lung worm disease in sheep, swine fever in pig and ranikhet in poultry.

(f) Pituitary Bank: Induced fish breeding techniques have been introduced using pituitary gland injection for producing fish seed.

(g) Farm Machinery and Implements: Some of the new implements developed include bullock-drawn sweeps, chisel plough, puddler, manual and animal drawn seed-cum-fertilizer drill, power tiller operated paddy harvester, tractor-oriented reaperbinder, multi-crop thresher, grain dryers for cereal crops, groundnut decorticator and sunflower and groundnut cracker. Many designs of biogas plants have been developed. Agricultural research in the country has acquired a new dimension. It now includes in its fold conservation, ecological infrastructure, energy management and transfer of technology. Biotechnology, as applied to agriculture, covers work in molecular biology, genetic engineering, biological nitrogen fixation, photosynthesis and protoplast fusion.

Advances in Communication Sector

Communications is one area in which significant developments have taken place in recent years in India. The strategy in this sector has been to import technology to strengthen the industrial base on the one hand, and developing an indigenous base for the absorption of imported technology, on the other. In effect, the country has acquired the capability to manufacture sophisticated material and equipment by itself. Particular mention can be made of switching and transmission systems and creation of support facilities like telephone instruments, digital telephones, key telephones and microwave and line systems. Recent work of the Indian Telephone Industries relates to digital telephone subscriber apparatus and instrumentation, telemeters, RTs and powerline carrier communication systems and integrated communication systems.

An aspect peculiar to India is the existence of vast inaccessible, rural areas with considerable linguistic and cultural differences. The R&D activities are rightly directed with considerable thrust to the development of hardware for the communication system in this context. The experiments relating to communication systems for rural areas conducted at the Space Applications Centre (SAC), Ahmedabad, have yielded encouraging results.

During the past four decades, substantial progress has been made in establishing a firm indigenous base for development of space science and technology. The mission of the space programme was to develop indigenous competence in designing and building sophisticated hardware, including rockets and satellites for providing point-to-point communication, in addition to application for meteorology and remote sensing of earth resources. The Indian Space Research Organisation (ISRO) has indigenously developed a family of rockets with diverse capabilities and instrumentation systems for atmospheric studies. They range from the single-stage RH-125 with a lift up of 7 kg payload to a height of 10 km to the two-stage RH-570 carrying a 100 kg payload to 350 km. Roelsets have been developed for the Rohini series with intermediate capability for meteorological purposes. Chaff and temperature sensors carried in these rockets enable measurement of wind and temperature in the region of 65 km altitude. Several of these rockets were successfully launched under the Monsoon Experiment Programme (MONEX).

A major landmark in the history of space technology in India in recent times is the launch of SLV-3-EO2 experimental flight (first generation launch vehicles of ISRO) on July 18, 1980, followed by the first development flight SLV-3-DI on May 31, 1981, and SLV-3-D2 on April 17, 1983. The success in a span of 3 years demonstrated the maturity of design and repeatability of fabrication of launch vehicles. With the precursors of SLV-3, there are Augmented Satellite Launch Vehicle (ASLV) and Polar Satellite Launch Vehicles (PSLV) in the perspective plan of ISRO.

The launch of Aryabhata in April 1975 from USSR marked an important step in the direction of developing capabilities in satellite technology. This was followed by the launch in June 1979 from USSR of Bhaskara, a remote sensing satellite, with a difference from Aryabhata in payload. Bhaskara II, launched in November 1981, carried satellite microwave radiometer payload, tape recorders and data collection platforms for solar cell experiments. It took over 2,000 TV pictures. Three Rohini Satellites (RS) have been launched into low earth orbit by India's own launch vehicles, the first one to evaluate the performance of the fourth stage of SLV-3, the second with a landmark sensor and the third with a 2-band imagery system (SMART sensor) for identification, classification of ground features, water resources and vegetation.

The most significant milestone is the launch of Ariane Passenger Payload Experiment (APPLE), India's first geostationary communication satellite, for experiments in domestic communications, radio-networking, data relay and remote area communications. Before positioning the communication satellite in the geostationary orbit, experiments were conducted on the technological and sociological aspects of satellite TV communications under the Satellite Instructional Television Experiment (SITE) in 1975 with the collaboration of US National Aeronautics and Space Administration (NASA). NASA's geostationary communication satellite was positioned suitably to re-broadcast TV programmes to over 200 villages using programmes from Ahmedabad and Delhi. The objective was to demonstrate the benefit of direct broadcast of TV programmes for rural development in the fields of agriculture, health and education. In 1977, the Satellite Telecommunications Experiment Project (STEP) was initiated in conjunction with Symphone, the France-German Geostationary Communication Satellite, to establish the feasibility of using satellite for domestic communication needs. SITE and STEP experiments provided a firm technological base in the communication sector. INSAT-1A and INSAT-1B satellite systems have contributed to successes achieved in domestic telecommunications, nationwide direct telecasting to rural areas and radio and TV programme distribution for networking.

In the field of electronics a wide variety of materials and equipment radars, television sets, broadcasting devices, telecommunication, switching and transmission equipment, earth stations, nuclear reactor control power electronics and under-water systems are produced within the country.

For purposes of modernization of the components industry, manufacture of new products have been taken up by the electronics industry: These are black and white, and coloured picture tubes, semiconductor devices, carbon film resistors, magnetic tapes, ferrite, electrolytic capacitors, PCBs, connectors, professional grade precision metal film capacitors.

A copper-beryllium alloy ingot plant has been set up for producing electronics materials and considerable progress has been made in the production of electronic grade alumina and liquid crystal materials. The National Silicon Facility (NSF) is involved in the development of ultrapure polysilicon, single crystal silicon, silicon wafers, ribbons and amorphous silicon. Capability has been established in digital electronic switching systems, electronic rural automatic exchanges (RAS) and message switching systems.

Indigenous technology has been developed in the area of mini-computer micro-processor based systems and mini-computers. Mini-computers are now manufactured by ECIL (TDC-332 and ICIM-2904). The mini-computers cater to various applications like accounting, word processing and teaching aids. Capabilities for manufacture of peripherals like CRT Terminals, floppy disk and dot matrix printer have been developed. Computers are revolutionising the activities in the country from image processing and medical diagnostics through photocomposition and numerical control of machines to intelligent testing and measuring equipment. The latest in these applications are control and instruments systems for offshore oil platforms and computer-based telesupervisory systems for cement production.

Technological capabilities developed in the electronics instrument industry range from the simple to the sophisticated: process control agro-dairying, medical, optical, geophysical, marine and electro-mechanical applications. In process control, instrumentation and design for an integrated electronic process control system for chemical industries, sugar, pulp and textiles. Programme sequence control systems have been developed for monitoring various parameters. Hundreds of sugar mills have developed for the Rohini series with intermediate capability for meteorological purposes. Chaff and temperature sensors carried in these rockets enable measurement of wind and temperature in the region of 65 km altitude. Several of these rockets were successfully launched under the Monsoon Experiment Programme (MONEX).

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Development of technological capability in space science/technology can be traced to 1823, when the Colaba Observatory was set up in Bombay. The next milestone was Indian Meteorological Laboratory (IML) in 1875. In 1926, studies were begun on ionosphere in Calcutta University. Studies in physics of the upper atmosphere, astrophysics and cosmic rays were confined to individuals till the establishment of the Tata Institute of Fundamental Research (TIFR) in Bombay, Physical Research Laboratory (PRL) in Ahmedabad and the National Physical Laboratory (NPL) in Delhi. Later, these programmes gradually evolved into systematic studies of earth's environment, inter-planetary space, solar physics and astronomy. The Department of Atomic Energy (DAE), entrusted with the mission of peaceful uses of outer space, set up the Indian National Committee for Space Research (INCOSPAR) in 1962 with the mandate of organizing the space programme in India. In 1963, the first rocket launching facility, the Thumba Equitorial Rocket Launching Station (TERLS), Trivandrum, was established for developing sounding rockets and scientific payloads. In 1967, an Experimental Satellite Communication Earth Station (ESCES) was set up in Ahmedabad in collaboration with UNDP and International Telecommunication Union (ITU) to meet the needs for trained manpower in space technology. These activities and agencies evolved in 1969 under the DAE into what has come to be known as the Indian Space Research Organisation (ISRO). In 1972, the Space Commission and the Department of Space (DOS) were set up by the Government of India under the direct control of the Prime Minister, the Chairman of the Space Commission being the Secretary to the Government in the Department of Space. The new department had the missions to generate and apply space technology for identified national socio-economic tasks. ISRO, the National Remote Sensing Agency and other organizations concerned with space were all brought under the executive control of DOS. ISRO is responsible for planning, programming, execution and technical management in the areas of space technology. It has four centres: The Space Applications Centre (SAC) at Ahmedabad, the ISRO Satellite Centre (ISAC) at Bangalore, the Vikram Sarabhai Space Centre (VSSC) at Trivandrum and the SHAR Centre at Sriharikota. DOS-supported R&D work related to space sciences and technology is conducted at the Physical Research Laboratory (PRL), Ahmedabad, and the National Remote Sensing Agency (NRSA), Secunderabad.

India has made major strides in the past four decades in the development and application of space science and space technology for the socio-economic benefit of the country. Satellite-based systems have an inherent edge over the conventional ground-based systems, particularly in communication. Though India's space programme has benefited substantially from external help, the stress has been on self-reliance in all the programmes, namely, satellites, launch vehicles, launching stations and space applications. The major research and development efforts that underpin the Indian space programme are carried out in the following units (the support facilities are also indicated): (i) The Vikram Sarabhai Space Centre (VSSC), Trivandrum, main centre for space research relating to sounding rockets and launch vehicles like ASLV and PSLV and maintains the UN-sponsored Thumba Equitorial Rocket Launching Station (TERLS) now forming part of IREX; (ii) ISRO Satellite Centre (ISAC), Bangalore, is engaged in development of satellite technology; designed and fabricated Aryabhata, Bhaskara I and II, Rohini and Apple; (iii) Space Applications Centre (SAC), Ahmedabad, is engaged in designing and fabrication of payloads, telecommunications and TV broadcasting and reception via satellite, survey of natural and renewable earth resources using remote sensing techniques, space meteorology and satellite geodesy; and (iv) National Remote Sensing Agency (NRSA), Secunderabad, operates aircraft flight facilities through India Photo-interpretation Institute and LANDSAT Earth Station near Hyderabad, using remote sensing technology and undertakes resources surveys for central government and state agencies.

The involvement of industrial undertaking in the highly exacting and demanding tasks relating to all these activities has led to the development of indigenous industrial infrastructure, capabilities and expertise in these fields. By 1990, it is planned to eventually replace the foreign procured INSAT spacecraft with indigenously designed, developed, tested and qualified operational satellites.

Advances in Construction Sector

Technological advances influence the way of life and this is particularly so in the construction sector. Development of automobiles, by altering inter-city communications, can bring about substantial changes in the town. The hinterland may warrant the development of satellite villages. With the projected growth in population and the implicit need for meeting the urban demands for housing, new methods of housing technology efficiency in the manufacture of building and construction materials, substitutes for steel, wood, cement and their energy intensity becomes vital. The technological options in the construction sector would beneficially cover mass housing cost effectiveness; special designs for heavy rainfall areas; fire resistance; urban complexes and services; materials; binders; plastics and polymers; energy efficiency; materials; construction methods; construction equipment; safety (speed) and seismic atlas and effects. The problem of building and housing at the national level is gigantic and the resources are very limited. The thrust areas appear to be urban housing and industrial structures.

The Central Building Research Institute (CBRI) at Roorkee generated and transferred the following technologies to engineers, builders, architects, government departments and construction agencies; precast roofing components, stone masonry block, CBRI high draught brick kiln, design of stadia, semi-mechanized production of bricks, manufacture of clay bonded flyash bricks, corrugated roofing sheets from wood wool-coir fibre, crack-free design of lime kiln, masonry cement from lime sludge, charging device for lime kilns, roof surface evaporative system for cooling buildings, fire-retardant treatment of thatch roofs, prefab brick panel system, non-erodable mud plaster for rural houses, low-cost latrines and waste water disposal system for rural areas. Tests and testing methods are also being developed for building materials such as lime stones, mineral wood mattress, slagwood, hydrated lime, bricks, rigid polyurethene, spintex and cement at the instance of the building industry, private agencies, Bureau of Indian Standards (BIS) and government departments. CBRI has been recognized as a centre of post-graduate study and research by the Universities of Agra, Banaras, Bombay, Madras, Poona and Punjab leading to Ph.D. in civil engineering.

The institute has patented know-how relating to automatic fire sprinkler, fusible release element, dual flushing cistern and pile boring rig. It has released the following processes to various industries: (i) CBRI high draught brick kiln, (ii) Lime sludge-based masonry cement, (iii) Corrugated roofing sheets from coir wastes/wood wool, (iv) Bored compaction piles, (v) Skirted granular piles, (vi) Wood wool boards, (vii) Flooring composition for railway coaches, and (viii) Improved furnace for burning of lime stones (5 T-day). CBRI has established liaison with research organizations in Canada, UK, USA, France, Germany, Sweden, Norway, Hungary, Kenya, Sudan, Jordan, Iraq, Iran, Thailand, Indonesia, Japan and Bangladesh for collaboration, exchange and import of technology.

The Central Soil and Materials Research Station, set up under the Central Water and Power Commission of the Ministry of Irrigation in 1954, conducts basic and applied research on construction materials, among other things. The broad functions of the station include work in the areas of soil mechanics, foundation engineering, rock mechanics and concrete technology. Contributions to technological capability in the construction sector have come through evolution of new designs and techniques of construction and engineering. These account for about 90% of the total technologies adopted by the industry. Thermal efficiency of kilns has been improved by the replacement of the conventional bulls' trench kiln by the high draught (HD) kiln. The HD kiln, used along with the CSIR developed semi-mechanized brick making machine, has reduced the capital requirement and increased its profitability; it has found wide acceptance in the brick industry and has almost totally replaced mechanized imported machines.

Nearly 50% of every five-year plan outlay goes into the construction sector. The construction component is significant in most of the sectors like agriculture, irrigation, communication, power, transport and industry in addition to the obvious requirements of housing and building. Construction technology also draws from allied sectors like materials of construction, construction equipment, foundations and structural design. High capability in this sector is evident from history; the Chola rulers of southern India in the first century A.D. were pioneers in the construction of dams and embankments. In this tradition, the country has built some of the world's largest dams and hydroelectric projects in the past 40 years. The following are among the major irrigation and multi-purpose projects completed: Nagarjuna Sagar, Thungabhadra and Pochampadu (Andhra Pradesh), Gandak, and Kosi (Bihar), Ukai (Gujarat), Ghataprabha and Malaprabha (Karnataka), Chambal (Madhya Pradesh), Hirakud (Orissa), Bhakra and Beas (Punjab, Haryana and Rajasthan), Farakka and Damodar Valley (West Bengal). The capability in building large earthern and masonry dams places India in the forefront in this area. Large hydroelectric stations involving major dams and powerhouses are still another national capability in the construction sector. The Idukki dam across the river Periyar in Kerala is the first-ever double curvature arch dam built using high quality concrete. Power stations of capacities up to 2,000 MW are under construction. A large network of roads involving impressive bridges such as the recently completed Ganga Bridge (Bihar) has been achieved. Over 8,000 km of border roads traversing high altitude terrains in the Himalayan belt have been built. Prestressed concrete and precast construction have become common in building projects in urban and industrial buildings.

Advances in Power Sector

The strategy for R&D in the power sector is evolved in the context of the overall objective, namely to extend the benefits of electricity at the lowest practicable costs maintaining acceptable standards of reliability. The need for R&D in the power sector was recognized as early as 1960, when the

Central Power Research Institute (CPRI) was set up as a national laboratory to take up research and development studies in transmission, distribution and utilization. It serves the needs of both electric supply utilities and electric equipment manufacturers. Its current R & D activities are largely in the fields of materials and equipment for HV and EHV (AC system) and its main thrusts are in the areas of testing and certification of high voltage transmission equipment. Testing and certification facilities are available in CPRI laboratories in Bangalore and Bhopal for materials/equipment/ appliances like LT switchgear, cables and capacitors, including partial discharge detection facilities, high voltage equipment, electronic system and instrumentation, liquid dielectronics with facilities for analysing chemical properties, domestic appliances, vibration (for transmission lines) prototype and model transmission testing and high voltage switchgear testing.

Some of the State Electricity Boards (SEB) have their own R&D cells oriented towards solving their operational problems. Major electrical equipment manufacturers, both in public and private sectors, have created in-house facilities to take care of their R&D needs. Their research activities are largely oriented towards product improvement and development, adaptation of imported technology to the local conditions and improvement of manufacturing processes. Important among these are the R&D units of Bharat Heavy Electricals Ltd. (BHEL), which are sprearheading the research activities in the manufacturing sector. Their R&D units are also engaged in basic research directed towards development of new technologies. Their R&D activities have the following major objectives, extension of the range of capabilities of the existing products, introduction of new products and processes with higher efficiency at lower cost, improvement in quality and reliability, import substitution of critical raw materials and components and basic analytical and experimental studies for exploitation and cost-effective utilization of the existing sources. BHEL, in cooperation with Bhabha Atomic Research Centre (BARC), is engaged in the development of thyristors needed in high voltage (HVDC) transmission systems and of MHD technology.

The Electrical Research and Development Association (ERDA), set up under the aegis of Council of Scientific and Industrial Research (CSIR) as a cooperative research and testing association of the Indian Electrical Manufacturing Industries and Utilities, concentrates on failure analysis of distribution equipment and boiler tubes. Their immediate target is the small-scale sector. The National Metallurgical Laboratory (NML) in Jamshedpur is engaged in carrying out research on development of suitable alloys for conductors and boiler tubes.

The Central Board of Irrigation and Power (CBIP) has been entrusted with the task of promoting and coordinating research in the power sector. The board is concentrating on the design, construction, operation and maintenance of power systems through research stations established by various State Electricity Boards, utilities and educational institutions. With its support, the meter and relay testing laboratories of the State Electricity Boards have been upgraded into research units for carrying out studies on the problems faced by the utility industries. CBIP does not have R&D personnel on its roles, as it functions mainly as a funding organization.

There is a need for further coordination in the R&D efforts in this sector. Significant R&D inputs are required on the methodology of load forecasting, power system planning, construction and proper management techniques, improvement of reliability and protection techniques of power systems, optimization of system economics, software development, computer application in power sector and EHV/HVDC transmission techniques.

The R&D strategy during the Sixth Plan emphasized on the need for improving the efficiency of production, distribution and utilization of all forms of energy, improvement of energy efficiency in processes and equipment, recycling of waste for augmenting energy supply and development of new and renewable energy technologies. Based on the above strategy, the following major R&D projects were included in the power sector: setting up an experimental line for research on UHV/HVDC transmission, contact or and transformer testing facility, setting up to 2,500 MVA short circuit testing laboratory, regional laboratories for routine testing of various types of power apparatus, research on problems of thermal power station operation (failure of boiler tubes, water chemistry, corrosion of fans and corrosion of coal conduits, geothermal investigation in Parbati and Puga valleys, studies regarding development of tidal power in Gulf of Kutch, problems connected with energy conservation and energy efficiency), agriculture and transport and establishment ot 5 MW (thermal) MHD experimental facilities. Many organizations are involved in the above projects. During the Sixth Plan the Central Power Research Institute (CPRI) incurred an expenditure of Rs. 180 million and the following are some of the significant R&D achievements: (a) development of special feed stock for producing high quality transformer oil, (b) use of gas chromatograph for transformer fault detection, (c) development of long duration timer for load shedding (d) evaluation of motor insulation system, (e) diagnostic generator insulation testing, (f) studies relating to quality improvement of high voltage 'PVC' and 'XLPE' cables, (g) development of PVC compound using indigenously available raw material suitable for use in 11 kV PVC cables, (h) development of narrow based 400 kV double circuit tower, (i) steam operated pumps using biomass as fuel, and (j) development of inexpensive high efficient wood burning stock.

The Central Electricity Authority (CEA) has established through a UN-assisted project by which thermal water in Manikaran area (Parbati valley) could find a number of non-electric applications. Utilization of this source of energy for spaceheating, hot water supply and dehydration of apples is being considered. Exploratory work in Puga valley is being pursued. CEA, along with Electric de France (EDF), is pursuing a techno-economic feasibility study of tidal power development in the Gulf of Kutch. An outlay of Rs. 32.4 million has been sanctioned by the Ministry of Energy. Department of Power has sponsored an R&D project on low calorific value gas warm up and low load stabilization system for 2×60 MW boilers at Ennora Thermal Power Station. The project, being implemented by BHEL, has the following objectives: (a) to eliminate consumption of oil in pulverised coal fired boilers, (b) to develop engineering capability for low CV coal gas consumption system for application in large utility (pulverised fuel fired) boilers with tangential firing system, (c) to collect engineering data on the integrated operation of the low calorific value coal gas combustion system in thermal power stations, and (d) to determine the economics of substitution of oil with producer gas.

The erection and commissioning of the gasifier and auxiliaries, coal preparation plant, fabrication and erection of gas and air ducts have been completed. The BHEL had an allocation of Rs. 310 million and the following projects have been completed: (a) Scientific Computer, Corporate and R&D Division, Hyderabad, (b) Coal Gasification and Combustion Facility, ESG, Hyderabad, (c) Materials Engineering Laboratory, CFFP, Hardwar, (d) Creep Test Facility, CFFP, (e) Augmentation of Test Facilities for Compressors, Hyderabad, (f) EP Flow Model Facility, Ranipet, Hyderabad, (g) EP Component Test Facility, Ranipet and (h) Impulse Generator, Jhansi. ERDA set up laboratories for undertaking research and testing and certification purposes at Baroda and an information and marketing centre at Bombay under Phase I of their programme at a cost of about Rs. 44.3 million. CBIP initiated studies on boiler tube failures, water chemistry and erosion of pulverised coal pipes (all in thermal power stations), performance of induced draft fans and electrostatic precipitators, at a cost of Rs. 36 million.

On the basis of the new perspectives developed for the power sector, the capacity additions required to meet the load demand have been worked out as follows: 27 GW during the Seventh Plan, 33 GW during the Eighth Plan and 50 GW during the Ninth Plan. The additional capacity requirement till the end century would be of the order of 110 GW. In working out the capacity requirements, some assumptions regarding improvements in the availability of the generating plants and efficiency of operation and reduction in transmission and distribution losses have been made. The targets appear to be technically feasible. Supply of coal of consistent quality to power station and reduction in the outage rates of thermal plants are expected to improve the operation of thermal power stations considerably. Rapid expansion of generation systems, economic considerations and limited availability of space and manpower required for setting up new thermal power stations have led to progressive adoption of large capacity thermal generating plant. With the introduction of high capacity thermal power stations, there is need to improve the availability of thermal plants so as to avoid large-scale systems disturbances due to high capacity sets suddenly becoming unavailable and resultant loss of generation. Wider application of computer and software development for the operation of regional grids in an integrated way is foreseen. Support from large computer systems would be required in almost all the studies in power development and electrical engineering; simulation and modelling, for computer aided design and manufacture and computer aided training. Development of suitable computer systems, microprocessors and associated software needs attention. There is large scope for setting up medium and micro-hydroelectric stations and these would require indigenous availability of low head-low discharge turbogenerating sets.

The above considerations indicate the directions R&D efforts need to take during the Seventh Plan. The goals and emphasis should be towards: (i) improvements in levels of operation, reliability and efficiency of generating plants and equipment; (ii) supply of coal of uniform and consistent quality to thermal power stations through coal beneficiation; (iii) development of fluidised bed combustion technology, enabling utilization of coal of inferior grades for power generation; (iv) evolution of standard procedures for integrated operation of power system; (v) wider use of computers and microprocessors in power sector and development of software; (vi) development of small size hydroelectric generating sets suitable for medium and microhydel projects; (vii) setting up of pilot solar and wind power plants and demonstration centres in different regions of the country to gather operational data under actual site conditions; and (viii) involvement of academic institutions in research programmes of relevance to utility and manufacturing industry.

In addition to R&D efforts for improving the overall efficiency of utilities by reducing transmission and distribution losses, a number of regional testing laboratories must be set up for the benefit of small electrical manufacturing units for third party certification of their products. Research and development work in emerging technological areas like MHD and high voltage DC transmission and energy efficient and reliable equipment needed by both the electrical supply industry and electricity consumers is also vital.

The thrust of research in the energy sector has been on improving the efficiency of production, distribution and utilization, recycling of waste and development of new and renewable energy sources, across the entire range of animal energy to atomic energy.

In the oil sub-sector, exploration of high priority indigenous sources of oil has received considerable priority. Capabilities have been developed for seismic surveying, reservoir engineering, design and development of offshore platforms and communication systems, ocean engineering for piping oil and natural gas from offshore wells.

For renewable sources of energy, two types of solar collectors have been developed and used in the fabrication of water heaters, dryers, wood seasoning machines, desalination plants, cold storages, power generators and pumps. A number of models of solar cookers have been developed: simple hot-box type with single reflector, solar ovens with multiple reflectors and solar concentrators. The production facilities at the Central Electronics Ltd. have developed to manufacture solar photovoltaic systems for water pumps and power systems (for installation on the offshore platforms of ONGC, for lighting TV and radio units). R&D work is being carried out on the production of high purity silicon for photovoltaic devices.

A number of firms are equipped to fabricate water pumping windmills. There has been intensification of R&D work on biomass production and conversion, including conversion of wood and agricultural wastes. Integrated energy projects based on different renewable energy sources are actually located in a number of sites. All these have been possible because the R&D organizations have been given mission oriented tasks of developing, demonstrating and commercializing.

In the field of atomic energy, technology has been generated in the following areas: exploration and mining of atomic minerals, preparation of high purity nuclear materials (uranium, thorium, plutonium and zirconium), production of fuel elements for reactors, design and construction of power reactors and their control systems, production of spent fuel and waste management. The agencies responsible for these are the Tata Institute of Fundamental Research, the Atomic Minerals Division, Bhabha Atomic Research Centre and the power projects divisions of various public sector undertakings. The R&D effort in the atomic energy sector is aimed at nuclear power generation and applications for developmental purposes like the use of radioisotopes in industry, agriculture and medicine.

The Department of Coal in the Ministry of Energy is responsible for exploration and use of coking and non-coking coal, low temperature carbonization of coal and production of synthetic oil from coal. The Department of Coal has the following agencies under its control: Neyveli Lignite Corporation and Coal India Ltd., and its subsidiaries, namely, Central Coalfields Ltd., Western Coalfields Ltd., and the Central Mine Planning and Design Institute Ltd. A Standing Committee on Science and Technology in the Department of Coal recommends, reviews and coordinates R&D projects. A Coal Scientist Award has been instituted by the department to recognise meritorious work in development/application-oriented research in the area. While Coal India Ltd. plans R&D activities in the sector, the Central Mine Planning and Design Institute has capabilities for giving expert advice on mineral exploration, planning and design of mining, mineral beneficiation and consultancy work in India and abroad.

In the sub-sector of petroleum. the constituent research instituted of ONGC have achieved a high level of technical capability; the development of the Bombay High is a significant achievement. The Indian Petrochemical Corporation Ltd. (IPCL) has a well equipped R&D centre; the Application Centre for Plastics and Rubber is a recent addition. Petrofile Corporation Ltd., a cooperative society, has capability for production of polyester filament yarn of the order of 3,500 tonnes a year. The Central Institute of Plastics Engineering and Tools (CIPET) at Madras, set up in 1968 by the Government of India with support from UNDP, offers training, development, testing, standardization, quality control and consultancy services to the plastics industry. An extension training centre of CIPET has been set up in Ahmedabad.

In the power sub-sector, the Central Electricity Authority (CEA) promotes research in electricity. It has undertaken consultancy projects in design and engineering of hydro and thermal power plants. CEA has rendered complete project design and engineering consultancy to thermal power projects in India and offered consultancy services for 36 hydroelectric projects, 9 of them abroad (Afghanisthan, Burma and Bhutan). It has transferred technology to a number of State Electricity Boards, departments and completed power projects in the design and engineering.

During the past 40 years, the Department of Atomic Energy has developed technological capability in nuclear science and various allied fields like chemical engineering, metallurgy, vacuum technology, reprocessing technology, fuel fabrication, waste management, radio-chemistry, radiation medicine, biology and food technology. These are spin-off effects. Further, technologies for exploration of uranium, reprocessing of spent fuel and recycling of plutonium have been developed. The facilities established include four research reactors, a fuel element fabrication plant and a plutonium plant. Technological capabilities were enhanced with the setting up of the plutonium plant in 1964, a reprocessing plant at Tarapore in 1979 and an experimental coal-based magneto-hydrodynamic plant at Tiruchirapalli (jointly with BHEL). The Variable Energy Cyclotron at Calcutta is accessible to universities for scientific experiments. The commercial radiation and sterilization plant at Trombay provides facility for sterilization of medical products. While BARC produces a large number of isotopes for use in industry, the Radiation Medicine Centre at Bombay provides for diagnostic and therapeutic applications of radioisotopes. BARC also evaluates levels of radiation exposure of workers in institutions using radiation sources and carries out radiological protection surveys.

About 150 scientific and technical personnel are trained at BARC training school every year; the nuclear training centre at RAPS, Kota, trains operation and maintenance personnel. In the area of nuclear physics, R&D work on fast breeder reactor technology, and survey, processing and development work relating to uranium, thorium, beryllium, zirconium, nickel-copper concentrates and finer magnetite is in progress. Capability has been built up for construction and operation of nuclear power stations and production of heavy water indigenously for use in the power reactors.

The R&D efforts put in so far have resulted in the indigenous development of some renewable energy systems which have crossed the laboratory stage and are ready for large-scale demonstration and field evaluation. The Department of Non-Conventional Energy Sources (DNES) has a programme of demonstration of various renewable energy systems with the following objectives: (i) to evaluate the performance of various devices and systems developed in the country under field conditions; (ii) to utilize the feedback to improve the products; and (iii) to promote awareness on renewable energy systems among various classes of users as well as planners, government officials and development organizations. The demonstration programme covers solar water heating systems, solar driers and kilns, solar refrigeration systems, solar distillation units and photovoltaic systems.

The utilization of renewable energy sources will continue to occupy an important place in the energy plan and scenario of India. The investment requirements are huge, but there is no alternative. There are possibilities of shortage of oil in the world market in the early nineties and this makes it all the more necessary for us to be ready with alternatives. This alertness is necessary in spite of the recent facts that (i) coal output is 154 tonnes (ii) generation of electricity is 136.81 billion KWh (iii) oil production is 26.5 million tonnes and (iv) during the next five years, India would be adding

5,000 MW of installed capacity annually. The vital areas for technological forecasting and technology assessment in the energy sector have been identified as thermal power, coal mining (movement and quality), role of oil and gas, hydropower (construction of plants, river resources and micro-hydel projects), alternative energy sources (biomass photovoltaic and nuclear power) and transmission (HVDC and superconductivity).

Advances in Manufacturing Sector

Advances made in science and technology have permeated to the manufacturing sector, resulting in rapid growth in textiles, jute, sugar, vanaspati, cement, paper, iron and steel, petrochemicals, fertilizers and mining industries. There are developments from fasteners to giant machinery, thanks to the 10 million tonnes a year of steel produced by the six major steel plants. The wide range of engineering goods are backed by major science and technology efforts in national laboratories, by R&D groups in industry and organised consultancy services. In addition to the laboratories under the direct control of agencies like CSIR, DRDO, ICAR, ICMR, Atomic Energy and Space Commission, several major centres like Research, Design, Standards Organisation (Railways), Central Machine Tools Institute, Telecommunications Research Centre and Central Water Power Research Station have provided enormous support facilities to the manufacturing sector. In the industrial sector there are over 30 units which incur on R&D expenditure of Rs. 10 million and above per annum. Significant R&D work has been done in the past few years by the following manufacturing establishments in the public sector: Bharat Heavy Electricals Ltd., Indian Petrochemicals Corporation Ltd., Hindustan Aeronautics Ltd., Indian Telephone Industries and the Steel Authority of India. Among the private sector units one can mention Ashok Leyland, Associated Cement Company, CIBA, Motor Industries Company and Hindustan Lever. Some of the consultancy organizations which have made notable contributions on the technology transfer in metallurgy, chemicals, petrochemicals, fertilizers, railways and communications are: Metallurgical and Engineering Consultants, Engineers India Ltd., Projects and Design India Ltd., Rail India Technical and Economic Services and Telecommunications Consultants India Ltd.

The Department of Industrial Development provides infrastructure for training, research and design facilities through a series of specialized institutions: (a) Tool Room Services—Central Institute of Tool Design (Hyderabad), Central Tool Room (Ludhiana), Central Tool Room and Training Centre (Calcutta), Central Institute of Hand Tools (Delhi); (b) Design Service—Institute for Design of Electrical Measuring Instruments (Bombay); and (c) Training Services—Small Industry Extension Training

Institute (Hyderabad), with a branch institute at Guwahati, and Integrated Training Centre (Nilokheri). The Department of Industrial Development has also established National Institute of Design (Ahmedabad), Cement Research Institute of India (New Delhi), Indian Plywood Industries Research Institute (Bangalore), Central Pulp and Paper Research Institute (Saharanpur), and Indian Rubber Manufacturers Research Association (Thane). The scope of Cement Research Institute has been enlarged and from April 1, 1985, it is known as the National Council for Cement and Building Materials.

Advances in Transport Sector

Transport is one area in which there has been spectacular development in India since independence. The country produces automobiles, railway engines and rolling stock, aircrafts and naval ships. This has been achieved by a combination of selective import of technology for technological infrastructure building and intensification of indigenous generation as a superstructure. A strong industrial base has been built meeting the requirements of the transport sector. Technology has also been developed to cater to the sub-systems of the transport sector like road networks, traffic signalling systems, bridges, airports and docks. These are, however, large systems. Progress has also been achieved in small-scale systems through indigenous development of cheap means of transport like road networks, traffic auto-rickshaws, mechanized crafts and river boats, in keeping with the socio-economic policies of the government. The current thrust of work in the sector today is on improving the operational efficiency of each transport system, energy saving and optimizing the costs and improving reliability of the material structures of the transport sector.

The R&D Research Panel of the Ministry of Shipping and Transport approved 36 research schemes in two packages (road research 27, and bridge research 9) during 1980-85. The following are some of the research schemes work on which has been completed: Highway Design Study (centres about evaluation of comparative performance of different pavement materials), Roughometers on National Highways (with a view to ensuring that the riding quality of roads when newly constructed is of acceptable standards), Traffic Simulation Modelling (to predict with the help of computer traffic characteristics for any combination of roadways and traffic factors), Bridge Research Schemes (large-scale models having clays on sides as well as base, realistic assessment of discharge in coordination with Railways, corrosion studies of expansion joints on road bridges and assessment of live road surcharge behind bridge abutments) and Bullock Cart Modernization. Some of these were jointly pursued by the Central Road Research Institute and the Transport Research Division of the Ministry.

The Research, Design and Standards Organisation (RDSO) of the Indian Railways has developed considerable technological capability in the sector. The RDSO came into being in 1957 through the merger of the Railway Testing and Research Centre (RTRC) and the Central Standard Office (CSO). RDSO is multi-disciplinary and fully equipped in terms of research facilities and personnel. It has on its staff researchers with the background of architecture, coaching stock, civil engineering, electrical motive power, signal and telecommunication and traffic research. There are specialists in bridges and tracks, steam and locomotives, airconditioning and cranes, and capabilities for giving advice and offering consultancy on technical matters to various operational and production units.

Within the ministry there is an apex body for research, Central Board of Railway Research (CBRR), having available to it the expert advice of eminent scientists, technologists, engineers and executives drawn from other research organizations, universities and industries directly or indirectly connected with the transport sector in general and the Railway technology in particular. The Chairman of the Railway Board is also the Chairman of CBRR, whose member-secretary is the Director of RDSO. One of the main functions of CBRR is to give guidance in RDSO in matters of the latter's research and development activities in the perspective of national socio-economic needs and interest and building up technological capabilities.

As mentioned earlier, the major R&D unit for the transport sector is RDSO. Another major consultancy organization, Rail India Technical and Economic Services (RITES), provides considerable support facilities to the railways sub-sector. RITES has completed a number of railway projects abroad. The Central Road Research Institute provides facilities for R&D work in the road sub-sector. The work of the various CSIR laboratories provides indirect support to the R&D requirements of the transport sector. The Transport Research Division of the Ministry sponsors research projects in a number of IITs and universities in areas of relevance. Some R&D activity has been taking place in the following public sector undertakings which come under the administrative control of the ministry: Shipping Corporation of India Ltd., Mogul Line Ltd., Hindustan Shipyard Ltd., Cochin Shipyard Ltd., Central Inland Water Transport Corporation, Dredging Corporation of India, and Indian Road Construction Corporation.

Underpinning these major efforts in areas of applied science and technology is a wide ranging programme of basic research carried out in the country's educational institutions and national laboratories. To popularise science and technology and to promote scientific and technological temper among people, a National Council for Science and Technology Communication has been set up.

Thousands of Indian scientists are now working abroad. A variety of incentives are offered to them for this efforts are being made to attract them back home where their skills are desperately needed. Efforts are also being intensified to encourage expatriates to offer their expertise in traditional as well as high-tech areas.

Planning

Ever since independence, programmes of planned development have always aimed at elimination of poverty, construction of modern society and attainment of self-sufficiency. The Seventh Plan also affirms these principles, but it provided for their integration into a fifteen-year perspective plan. The aims of this perspective plan are: putting an end to illiteracy, achieving near-full employment, increasing productivity, meeting the basic needs of food, cloth and shelter, and ensuring health for all. It has been specified in the plan that the idea is to transform the structure of the Indian economy and to do this "it will be indispensable to take full advantage of the progress in science and technology."

During the last four decades, the Planning Commission has evolved an elaborate process for the formulation of plans. The commission sets up working groups of experts in collaboration with the central ministries and state governments. In the field of scientific research, commission sets up independent committees, working groups and panels of experts and scientists to suggest plans for various sectors of scientific research. It may be emphasized that the national socio-economic development plan strategies for the Seventh Five-Year Plan (1985-90) are very relevant for the formulation of technology policy planning. It may also be proper to view this in the background of the legacy of the Sixth Five-Year Plan (1980-85). During 1979-80, there was an unprecedented drought, weather conditions were unfavourable during 1982-83. There was a 17% fall in foodgrains production and thereby a rise in prices. Infrastructural facilities deteriorated. Throughout the plan period, the supply of wage goods consumption is necessary for subsistence and work grew at a rate of about 2.5% per annum. This was more or less the rate at which population had been growing. In effect the poverty line proportion (50% of people in absolute poverty) remained more or less constant. In spite of these handicaps thanks to the soundness of the basic strategy, the Sixth Plan had yielded good results during the terminal points. The target rate of growth of 5.2% was more or less accomplished. The mobilization of resources had reached a record high. Public sector investment had risen at an annual rate of about

10%. Nearly 94% of the cost of investment had been met from domestic savings, which is a good sign of self-reliance in the economy. The buffer stocks of foodgrains reached new heights. The country's foreign exchange resources touched a record level of Rs. 6,300 crores, that to the 12% rate of growth of exports and sizeable inward foreign remittances.

Emphasis in the Seventh Plan is on food, employment and productivity. To elaborate this, the following are objectives: (i) growth with equity and social justice; (ii) agricultural and industrial growth with growth of infrastructural facilities such as power, coal, transport and communication sectors; (iii) growth of non-inflationary employment with emphasis on rural sector through NREP and IRDP with cluster/group of programmes approach; and (iv) improved efficiency and productivity and self-reliance.

The approach stresses the human factor. It emphasises that the plan should reflect the popular aspirations, recommend high-technology development in crucial areas and caution against environmental hazards. It postulates a growth rate of 5% per annum, envisages a savings rate of 26% and proposes a total outlay of Rs. 320,000 crore for the period 1985-90 at 1984-85 prices. The public sector investment is expected to be of the order of Rs. 180,000 crore. Resource mobilization is to be attempted to avoid resorting to deficit financing and reliance on external sources. A reduction in the capital-output ratio through better capacity utilization is contemplated. The approach emphasizes faster growth of exports of engineering and non-traditional items and self-reliance in oil-seeds and petroleum products. It aims at massive programmes of irrigation for agricultural development, endowments of income-generating assets in the core of anti-poverty programmes, developments of such employment generation programmes which will cause a shift of the rural population from agriculture to secondary and tertiary sectors and public distribution of essential commodities to the vulnerable sections of society. A population growth rate of 1.8% per annum is the target for the end of the Seventh Plan. One of the projections puts the population in 1990 at 803 million.

The policy of technological self-reliance being followed does not mean technological self-sufficiency. The government policy is being directed towards reducing the technological dependence in key areas. Further, the spirit of innovation and invention is the driving force behind all technological change. The objective has been to awaken science and technology to the existing challenges and to provide incentives to encourage inventors to direct their efforts to area of special importance. In technology development, special emphasis is being laid on food, health, housing, energy and industry. In particular, the stress is on: (i) agriculture, including dry land farming; (ii) optimum use of water resources, increased production of pulses and oil-seeds; (iii) provision of drinking water in rural areas, improvement of nutrition, rapid reduction in the incidence of blindness, eradication of the major communicable diseases (such as leprosy and tuberculosis) and population stabilization; (iv) low-cost housing; (v) development and use of renewable non-conventional sources of energy; and (vi) industrial development.

Since independence spectacular growth has taken place in the key sectors of health, transport, communications, energy, housing, textiles, fertilizers, chemicals and capital and consumer goods through planned investment in education and research. The transformation achieved from a small base to current levels is remarkable, thanks to the importance given to the development of science in all aspects. During the past four decades, production of food has increased from 50 to over 150 million tonnes, of coal from 30 to 143 million tonnes and of petroleum produces from 1 to 40 million tonnes. The average of life expectancy has increased from 36 to 57 years.

The credit for all these achievements would not go to scientists and technologists alone, but also to the patrons of science. The progress in science and technology in the country owes a great deal to the patronage of Jawaharlal Nehru and later to Indira Gandhi and Rajiv Gandhi.

Mrs. Gandhi, like her father, was in-charge of major scientific establishments—the Departments of Atomic Energy, Space and Electronics, two major pillars of modern science. It was her undivided devotion and faith in science that placed India on the map of science. India made rapid strides in science during Mrs. Gandhi's tenure of office. Among the major landmarks are the indigenously developed nuclear reactors, fabrication and launching of Indian satellites and extensive coverage of television programmes through INSAT, besides the nuclear implosion at Pokhran for peaceful purpose, offshore oil drilling, scientific expeditions to Antarctica and self-sufficiency in a wide variety of areas of science.

During the first three years of Rajiv Gandhi's assumption of office, computers entered the Indian scene in a big way and a number of high-tech babies were born. Significant advances were witnessed in the fields of nuclear energy and electronics. Atomic scientists commissioned three reactors, space scientists ground tested their advanced launch vehicles and farm scientists produced bamboo, coconut and sandalwood in test tubes. India also joined advanced countries in development of high temperature superconductors.

Task Ahead

Impressive as the achievements are the challenges in the next 12 years ahead are formidable. The population is expected to increase by 20 million and the life expectancy at birth to about 63 years. At present 38% of the total population is below the age of 15, requiring care and attention in health, nutrition and education, so that they can grow and develop to make major contributions to national welfare and prosperity. Foodgrain production is expected to go up to 240 million tonnes. In other sectors, the demand for coal and lignite will increase by 280%, use of petroleum by 120%, cloth by 75%, cement by 200%, fertilizers by 200%, steel by 133% and electric power generation by 250%.

The task ahead is not only to increase the output of goods and services but also to improve the quality of life of our people. The country is committed to the abolition of illiteracy and provision of good health for all by the turn of the century. Even during the Seventh Plan (1986-90) enrollment of children under 15 years will have to increase by 50 millions and the process has to be accelerated in the following ten years. In higher education, opportunities have to be provided for vocational training and technical education.

While improving the quality of life, considerable attention is needed to be paid to putting an end to the degradation of the natural resources of productive land, and making a massive effort at restoration. It is planned to increase forest cover from the present 23% of land area to 33% by the year 2000 by improving the existing forests and by recovering 5 million hectares of wastelands for forestry each year. Similarly, major efforts will need to be made to free natural waters of pollution from industrial effluents. Soil conservation and water management have to receive much attention as also the improvement of hill areas for ensuring ecological balance.

These objectives of transformation require the application of the very best technology. In such programmes, the most effective and efficient technological solutions have to be found, so that the maximum advantage is obtained from the use of financial resources.

Energy conservation will have to be accorded high priority. Likewise, energy generation from a variety of fossil fuels has to depend on the most efficient systems and has to be supplemented by better use of sources of renewable energy. In the case of renewable sources, technological improvements can make major contributions.

Given these targets, it is imperative to harness the established knowledge in technology as well as emerging technologies to obtain the maximum advantages in all systems. Fortunately, a sound base in infrastructure and human resources has been nurtured in the country.

In the areas of land and water usage and agricultural and animal productivity, there are opportunities for application of biotechnology.

While the conventional techniques of genetic improvement of plant and animal breeding will continue to improve varieties and give yields suited to different requirement of soil and climate, modern techniques of genetic engineering, plant tissue culture will play an increasing role.

Diascorea species producing diosgenin are the major raw material for pharmaceutical and contraceptive steroids. New cell fusion technologies can confer spectacular genetic properties. It is also possible to transfer a genetic property from one species to another providing resistance to viruses or pests or to drought conditions. There are also developments in the use of biofertilizers through application of algae. The efficient soil microbial agents involved in biological nitrogen fixation, such as *Azatobacter* and *Kleibella*, can be selected and improved, cultured and distributed. It is possible to envisage the production of cereals at levels of 12-15 tonnes per hectare per annum in comparison to the national average of 2-4 tonnes. In the case of oil-seeds, yields of 3 to 4 tonnes per crop per hectare are realisable by the judicious use of seeds, fertilizers and pesticides.

In the case of forestry, similar high-yielding tree varieties of teak, eucalyptus and bamboo are important components for propagation by tissue culture.

There is wide scope for use of biotechnology in animal productivity. *In vitro* fertilization from high quality stock and embryo transplant have been demonstrated and will have major effects on the rapid development of large number of animals of high productivity in cattle, sheep and goats. Genetic engineering and cell-based culture are generating highly specific and effective vaccines to protect animals from communicable disease. These are based on identification and isolation of the genetic component producing antigens of antibodies related to infecting microorganisms or pests and transferring them to bacterial cells which can then be grown in fermenters.

It is in the area of human health that modern advances in new biology will have the most visible effects. Human insulin is now industrially produced by genetic engineering from microbial culture and encapsulated insertions should provide continuous control for diabetes. Human growth hormone has been applied to correct dwarfism. Effective vaccines are available for polio, diphtheria, rabies and tetanus. There are clear indications of future availability of vaccines against cholera, diarrhoeal diseases, pneumonia and infectious hepatitis. It will be possible in the next decade to develop vaccines against malaria and other parasitic diseases which afflict a very large percentage of the Indian population. Sensitive procedures are likely to be developed for early detection of diseases such as leprosy, incipient heart diseases and their timely remedy by new biochemical agents. There are ambitious schemes for the regulation of human fertility through vaccines.

Biotechnology will have application in the removal of pollutants from effluents in mineral beneficiation and in exploration for coal and hydrocarbons as well as in industrial processes for the production of alcohol and other chemical feedstocks from agricultural materials, and in improving nutritional value of animal feeds. It is already being tried for control of malaria parasite in waterbodies.

Advances in the production of new materials, such as polymers, composites, high strength, light-weight alloy ceramics are bringing about remarkable changes in industrial and consumer goods, transport systems, industrial processes, and in biomedical applications. Materials for bodies, engines and interiors in automobiles, boats, ships and aircraft will have a large proportions of new lightweight materials which are resistant to corrosion.

In industrial processes, membranes, and catalysts from new materials will have far-reaching effects in improving separation and purification, chemical synthesis, pollution abatement, etc. Energy conservation will be highly dependent on these developments. These materials will also be used in surfacing of roads. These will increasingly replace steel and metals in applications related to aerospace, defence, telecommunications, electrical power transmission and storage batteries. New developments will lead to self-repair systems. Reduction of frictional losses in all rotating machinery will be achieved with these. They will find large-scale use in electronics, computers, television, photography, mining materials handling and conveying pipelines transport and in enhanced safety.

A variety of energy conversion and energy storage and delivery systems are being developed using new materials. These include amorphous photovoltaics, high efficiency solid state batteries, windmills, fuel cells, photo electrolysis of water, photo conversion of nitrogen to ammonia, spring energy storages. Electrical power conducting polymers can replace metals in cables. Very thin film formation techniques can reduce cost in photovoltaics. Special materials can absorb large quantities of gases and liquids and release them for use as fuel. Transparent materials with the ability to reflect or absorb specific portions of sunlight and other radiations have application in energy conservation and in night vision devices. In optical instruments, spectacles and photographic equipment, new materials are replacing glass. Advances in nuclear power generation too will need the use of newer materials.

The extraordinary efficiency in communication systems arise from new materials used in lasers, fibre optics, microprocessors, digital electronic exchanges and satellite systems, television receivers and telephones.

The advent of electronics, micro-electronics, data storage and analysis with very large computers has ushered in the age of information technology. Together with many new instrumental sensors and communications, electronics has entered every sphere of activity. A massive programme for the application of electronics has been formulated and it is anticipated that the value of electronic goods produced in India will exceed Rs. 10,000 crore by 1990 and it will rise to Rs. 50,000 crore by the year 2000. Electronics is being introduced in the sections of steel, chemicals, fertilizers, polymers, cement, paper, synthetic fibre, textile, mining, power generation and transmission, and medicare and entertainment with considerable savings and increase in efficiency.

The National Informatics Centre is establishing a network with regional centres and with large data processing systems at Delhi, which, in turn, are connected to government departments and agencies. There are also projects on artificial intelligence which will lead to the next generation of supercomputers. Simultaneously, the world over, work is in progress towards higher storage and processing capability through a variety of approaches to the design and production of very highly integrated systems.

Developments are fast taking place in the design of robots and introduction of automation in industry, mining and transport sectors, where a large proportion of tasks are repetitive and performed under demanding environmental conditions. These have to be performed continuously in hazardous conditions like work at high and low temperatures or under ionising radiations. The use of robots for such tasks is being attempted. There are also very high degrees of standardization and precision in components for industry. Simplification of the numbers of components, machinery architecture based on standard components, and assembly are leading to flexible manufacturing systems. These have effect on the future course of cost effective production of industrial and capital goods and consumer durables.

In the traditional areas of power generation from coal, the increased need for coal and transport could be met by pipeline slurry transport. A demonstration project on Indian pilot work has been conceived. Fluidised bed combustion for steam raising allows high ash coal as well as agricultural wastes to be utilized efficiently. Coal gasification and combined cycle power generation are projects which can increase the availability of energy from coal by a quarter.

In the oil and gas exploration programmes, a combination of newer techniques and computer modelling is becoming essential. It will be necessary to explore for hydrocarbons by deep and very deep drilling and produce petroleum from such depths; this will require new technologies, equipment and systems. Production offshore from deeper structures also is demanding new technologies. Imaginative exploration work is being done to locate lignite at deep levels in Gujarat underground gasification as a means of producing energy. Long wall mining with new equipment and technologies is being adopted to increase coal production. Coal washeries are also required on a large scale for beneficiation.

New technologies are emerging for the production of steel involving continuous direct reduction by feeding together powdered ore and coal and removing metal continuously. From the high temperature flue gases power is generated. A major demonstration project is being formulated. Advances have been made in the production of magnesium by electrolysis and displacement processes. Special materials like titanium and gallium are to be produced using indigenous technology. From the excellent base of metallurgical processing experience and through research and development, a variety of sophisticated alloys and alloy products are already being manufactured. These are needed in petrochemicals, fertilizers, oil refining, and nuclear power industries as well as for aircraft and defence equipment.

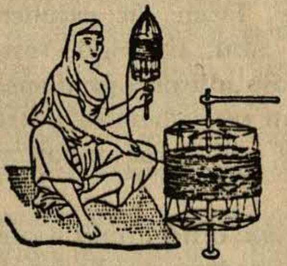
Strategies in nuclear power generation and other applications of atomic energy, there is steady progress. The space programme also involves orderly development of new materials and systems with exceptionally high reliability. From these there are many results that can have beneficial applications in other fields such as magneto hydro dynamics, power generation, radiation disinfestation of foodgrains by radiation, sterlization of medical products, low-temperature refrigeration, new measuring scientific equipment, special chemicals and emerging polymers, control systems, special high power magnets, robotics, high temperature ceramics, special pumps and valves. Advances in defence research have also potential for application outsides. Attempts should be made to identify these. A particularly exciting integrated project is the development of a light combat aircraft involving new materials, controls, designs and stringent evaluation.

Among the few examples of the new directions in technology so essential for rapid transformation are ocean bed surveys and mining, development of natural primary standards and their maintenance, advances in construction of bridges, dams and underground tunnels, link canals, roads in high altitude border areas, offshore oil and gas production platforms, sub-sea pipelines, harnessing of wave and tidal energy.

No less important are systems for micro-hydel energy, geothermal energy, water lifting by pipelines in mountains from waterfalls, small efficient agricultural machinery, improvements in loans for weaving, new designs for urban and rural transport, location of water resources in drought-prone areas and low-cost construction.

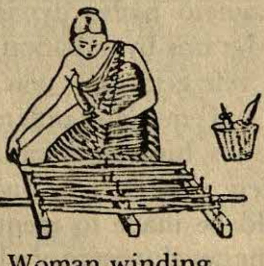
Wood turner
and his assistant.

Dyeing
hanks of silk.

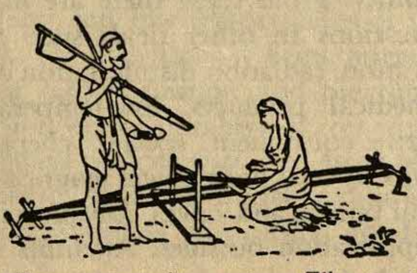


Woman winding
dyed silk.

Woman
spinning cotton.



Woman winding
cotton thread.



Woman weaving cotton. The man
carries a bow for cleaning the cotton.

Beating canvas.

Making a loincloth on a vertical loom.
The man is knotting the threads.

A picture showing traditional technology.

Despite impressive record of achievements of the past four decades and new directions given in various fields there is much to be desired as far as commercialisation of indigenously developed know-how is concerned. While a large number of indigenous processes have remained fallow, the number of foreign collaborations has increased from 183 in 1970 to 389 in 1981, 673 in 1983 and about 750 in 1986.

More than 75 per cent of electronic items, 70 per cent of agricultural machinery, 65 per cent of transport machinery and 35 per cent drugs and pharmaceuticals made in the country are product of foreign collaboration. Furthermore, about 80 per cent of the foreign collaborations have been renewed between two and five times, and 20 per cent six times or more. Although the solutions to the problem of indigenous technology are partly provided in the Seventh Plan, which seeks to establish linkages between science and technology institutions, the university system, industry and beneficiaries, still serious efforts are needed to be made in using the fruits of indigenous science and technology particularly in improving quality of life of the poorest of the poor living in rural areas and urban slums.

Last but not the least, a sound infrastructure for pursuing science at its frontiers has been built up in the country. At the same time, India has succeeded, to some extent, in using the benefits of indigenous technology for solving developmental problems. The achievements of the past 40 years and new directions given in various fields may enable the country to move forward with a greater purpose and a sense of direction in achieving the new goals and challenges ahead in the 21st century.

As the celebrated Indian scientist C.V. Raman said: "Unless the real importance of pure science and its fundamental influence in the advancement of knowledge are realised and acted upon, India cannot make headway in any direction and attain her place among the nations of the world.... There is only one solution for India's economic problems and that is science, and more science, and still more science".

Atomic Energy

INDIA HAS developed expertise in all stages of the nuclear fuel cycle, and created indigenous capabilities in designing, construction and operation of nuclear power plants, reprocessing of spent fuel, and manufacture of the necessary sophisticated equipment. Capabilities have been created right from exploration and mining of atomic minerals, preparation of high purity nuclear materials, such as uranium, thorium, zirconium, etc., production of fuel elements for reactors, production of heavy water, health and safety instrumentation to nuclear waste management.

Though the country had a rich and varied tradition of fundamental research, organized studies in nuclear science began only in 1945, with the establishment of the Tata Institute of Fundamental Research. Thereafter, in 1954, a major part of the work on atomic energy was moved to Trombay, where a multi-disciplinary centre for research and development (the Atomic Energy Establishment, Trombay) was set up. In 1967, the centre was renamed as Bhabha Atomic Research Centre (BARC) in memory of its founder.

The prime objective of the atomic energy programme, as defined in the Atomic Energy Act of 1948, is the development, control and use of atomic energy solely for peaceful purposes, namely, the generation of electricity and the development of nuclear applications in research, agriculture, industry, medicine and other areas. To achieve this objective, efforts were initiated to build up a versatile infrastructure of research facilities, trained scientific and technical manpower, raw material processing centres and the know-how and capability to manufacture nuclear components and electronic equipment to support the atomic energy programme and make India truly self-reliant.

Thus, India started work on the peaceful utilization of nuclear energy at a time when it was essentially very much of a frontier science, into which a few developed countries alone had ventured. At a conference held in November

1954 in New Delhi on the Development of Atomic Energy for Peaceful Purposes in India, the late Prime Minister, Pt. Jawaharlal Nehru, in his inaugural address said, "So far as peaceful purposes are concerned, obviously we want atomic energy for the generation of power. Power is the most important thing in developing a country's resources."

The nuclear fuel cycle strategy which India would follow was chalked out by Dr. Bhabha at the same conference in 1954, namely a first stage of natural uranium reactors for producing power and plutonium, a second stage of plutonium based fast breeder reactors for producing power and more plutonium as well as uranium-233 using thorium, and a third stage of uranium-233-thorium breeder reactors for producing power.

In spite of innumerable hurdles which had to be overcome and notwithstanding other hurdles which may be encountered in the future, India has not deviated from its carefully chosen path of using nuclear energy for peaceful purposes. By now, considerable financial and manpower resources have been invested, not only by Government but to a large extent by industry as well, towards achieving this objective. India has reached a stage where it has a sound infrastructure of industry and know-how to support and sustain all the required activities encompassing feasibility studies, detailed project design, construction, installation, commissioning and operation of any plant in the entire fuel cycle chain. India is among a handful of countries, and the only developing country, to have developed capabilities in respect of the complete fuel cycle right from uranium exploration, mining, extraction and conversion, through fuel fabrication, heavy water production, and reactors, to reprocessing and waste management. In attaining this degree of self-reliance, India has earned for itself a place among the countries most advanced in the technology of atomic energy.

Exploration, Mining and Extraction of Atomic Minerals

Geological investigations over 50 years ago established the presence of rare earths in the beach sands of Kerala. In fact, private companies had been processing and even exporting these sands and certain processed products since 1911. Similarly, occurence of uranium minerals was reported more than 40 years ago. Detailed geological surveys for uranium and thorium were, however, initiated only in 1950.

The exploration strategy in India has been oriented to development and optimum utilization of improved exploration techniques and instrumentation, interpretation of indirect geological evidence, identification of newer favourability factors to understand formation of deposits and recognition of favourable areas in the light of additional geological data. The investigations conducted so far for uranium have indicated that almost all major deposits are located in the Peninsular Shield, the major part of the reserves being in the state of Bihar. The search for favourable localities for uranium mineralization in the Peninsular Shield culminated in the discovery of the Jaduguda deposits in Bihar. This provided tremendous impetus for intensifying efforts in other similar favourable environs in the country, as also to the development of various techniques and instrumentation required at various stages of exploration. The existing techniques have undergone continuous refinements and new and sophisticated ones have been added. The work done has also helped in adding to the knowledge and understanding of various geological processes governing the formation of uranium in what are identified as sandstone type of deposits.

The major occurrences of uranium deposits in the Peninsular Shield are in vein type of deposits. Nearly 300,000 metres of drilling in almost 45 localities in Bihar has established a potential exceeding 3,000 to 5,000 tonnes of U_3O_8 in three locations and 1,000 to 2,000 tonnes each in seven localities. Among these, the Jaduguda deposit is the most favourable one and is presently being commercially exploited. New target areas have recently been identified in the state of Madhya Pradesh, where nearly 2,000 metres of drilling to depths up to 400 metres has established a deposit. Extensive aerial and field investigations are under way in other parts of the country where uranium deposits are present in conglomerates, sandstone, and other geological formations. Uranium has also been located in the copper and phosphate deposits, from where it could be recovered as a by-product.

An important fallout from the survey activities has been the development of instrumentation required at various stages of exploration. A direct reading survey meter has been developed which directly displays the equivalent uranium concentration in digital form. This instrument works on four standard size batteries. A gamma-ray spectrometer has been designed which uses, besides pen recorders, a digital tape recording system for estimating uranium and thorium concentrations. Plastic film track detectors are being used increasingly; a modified version developed recently enables discrimination between the radon and thoron readings.

As a result of the extensive survey work carried out so far, it has been estimated that India's total uranium reserves are about 73,000 tonnes. India's thorium resources contained in the monazite beach sand, as well as some inland deposits, are estimated at about 363,000 tonnes, the largest in the world.

Instead of depending on foreign collaboration in uranium exploration activities, India decided to develop the techniques on its own. This led to not only the development of inter-disciplinary manpower and team work but also survey techniques more appropriately suited to local conditions. Today, India is in a position to offer assistance to other developing countries in uranium exploration and to take up turn-key aerial and land based exploration assignments abroad.

In 1952 a rare earths production plant was set up at Alwaye in Kerala to process monazite from the beach sand deposits. This plant produces uranium-thorium concentrate as a by-product. By 1955 a thorium plant was set up at Trombay to recover from this by-product thorium nitrate (which is widely used in the gas mantle industry) and uranium fluoride. This plant is still in operation and has provided all the thorium needed for various research and development programmes. The construction of a uranium plant was started in 1957 at Trombay and the first ingot of uranium of nuclear purity was produced in 1959. This plant was primarily put up in order to gain first-hand experience in the production of nuclear-grade uranium metal. It had practically no teething troubles and still continues to be in full production.

Technology has also been developed for recovery of uranium as a by-product of copper. Laboratory studies followed by pilot plants established the economic feasibility, and uranium recovery plants have been set up adjacent to copper mines at Surda, Rakha and Mosaloni in Bihar.

The conversion of 'yellow cake' into nuclear-grade uranium and, thereafter, the fabrication of fuel elements was developed completely indigenously in India. On the basis of development work carried out at Trombay, the preliminary flow sheet for a conversion and fuel fabrication plant was finalised by the end of 1957. The fabrication plant was completed in less than 20 months. The first fuel elements for the CIRUS reactor was fabricated by mid-1959 and the fuel elements for half of the first charge of CIRUS were made by mid-1960. Thus, about twenty years ago, India had already developed and built a fuel fabrication plant fully based on indigenous technology.

The Trombay plant, in addition to being used for the production of fuel elements for India's research reactors, has also been used for R&D on new fuels and materials. Thorium oxide and sintered thorium metal pellets have been produced for irradiation experiments. All the thorium oxide pellets required for India's Fast Breeder Test Reactor have also been fabricated.

Most important of all, processes were developed for the production of ceramic grade nuclear pure uranium oxide pellets. Half of the initial loading consisting of 2500 zircallon-clad uranium oxide fuel assemblies required for the first unit of the Rajasthan atomic power station was fabricated at Trombay. Thus with the R&D activities, followed by pilot plant operations at Trombay, India had, almost 25 years ago, became one of the very few countries with the capability of producing nuclear fuel elements for power reactors.

With the successful demonstration of the technology developed in Tromblay, a Nuclear Fuel Complex was set up in Hyderabad in 1971. This complex essentially consists of plants for conversion of yellow cake into ceramic grade natural uranium oxide and imported hexafluoride into enriched uranium oxide, for processing the zircon sand to zirconium and various finished zircalloy components such as tubes, sheets, rods and wires, and for making sintered uranium oxide pellets and fabricating the required fuel elements. The Nuclear Fuel Complex is an example of successful translation of indigenous R&D into industrial operations. The activities of the complex are being diversified to produce seamless stainless steel and ball bearing steel tubes.

The fabrication of plutonium fuel is an extremely difficult task because of its toxicity and has to be carried out in glove boxes. At Trombay, another important event was the fabrication of the plutonium oxide fuel elements for the PURNIMA reactor in the plutonium metallurgy laboratory built in 1970. This laboratory will be used to fabricate the fuel element required for the Fast Breeder Test Reactor which attained criticality on October 18, 1985, at Kalpakkam, Tamil Nadu. A plant for fabrication of the components for the Fast Breeder Test Reactor fuel assemblies has been set up at Hyderabad. The development of plutonium handling technology is essential for India's second stage fast breeder reactors. By the time a decision is taken to construct a commercial breeder reactor, the plutonium handling technology will be adequately developed to enable the necessary scaling up of operations to be successfully accomplished.

Heavy Water Production

Heavy water is used as a moderator in CIRUS and as moderator and coolant in DHRUVA and in all Indian nuclear power reactors, with the exception of the Tarapur station. With the objective of achieving self-sufficiency plans for the indigenous production of heavy water were formulated as early as 1954. Based on initial investigations, it was concluded that heavy water production would be economical if set up in combination with nitrogenous fertilizer production. To start with, a heavy water plant based on electrolysis of water technology, was set up at the Nangal fertilizer factory. It has a capacity of about 14 tonnes per year and has been in operation since 1962.

Meanwhile R&D on heavy water technology at Trombay continued. First, a heavy water reconcentration facility was set up in 1962 for upgrading the downgraded heavy water from the CIRUS and ZERLINA reactors. Later, an upgrading test facility was also set up based on the electrolysis process. This experience in upgrading at Trombay has enabled the design of heavy water upgrading plants for the Rajasthan and Madras atomic power stations.

As the country had opted for heavy water reactors for its nuclear power programme, mainly because this reactor type uses natural uranium fuel, it then became necessary to also concurrently embark on the construction of heavy water production plants. For the first heavy water plant at Kota, the hydrogen sulphide water exchange process, which was developed indigenously at Trombay and proven on a pilot scale, was chosen. This plant is designed to produce 100 tonnes of heavy water annually and will utilize steam and power from the Rajasthan atomic power station. A similar plant using hydrogen sulphide technology is under construction at Manugram (Andhra Pradesh).

In addition, four more heavy water production plants based on ammonia-hydrogen exchange process have been installed adjacent to fertilizer plants. These are the 67-tonne plant at Baroda, the 71-tonne plant at Tuticorin, 62-tonne plant at Talcher and 110-tonne plant at Thal in Maharashtra, which have started production. Another ammonia-based plant is under construction at Hazira in Gujarat.

Research Reactors

In the field of research reactors, India's expertise in design, construction, installation, commissioning and operation has been gradually developed over the past 40 years. In 1954 it was decided to build a 1 MW swimming pool reactor (APSARA) and although such reactors were readily available in sale from some developed countries, it was considered that valuable experience would be gained if Indian scientists and engineers were to undertake the task. By 1955 the design was frozen and by the following year construction was completed and the reactor became critical by mid-1956. Under the conditions prevailing then, this was recognized as a remarkable achievement as even among countries then considered advanced in the nuclear field, only a handful had built their own reactors. In 1956 APSARA was the only reactor in Asia outside the USSR. Even today APSARA, which is likely to be retired soon, continues to operate and is used for the production of isotopes and for experiments in physics.

About the same time that a decision was taken to build APSARA, attention was given to a high flux reactor for engineering experiments, materials testing and isotope production. In 1956 it was decided to build CIRUS, a 40 MW natural uranium heavy water moderated reactor, with Canadian collaboration. Indian personnel were associated with the

Canadian in all stages of construction, installation and commissioning of this reactor. An important achievement was the entirely indigenous fabrication of half of the initial fuel charge in a fuel fabrication plant that had been set up with indigenous R&D and know-how. The reactor became critical in mid-1960 and continues to operate providing valuable production, experimentation and training facilities.

In early 1961 a zero energy reactor, ZERLINA, was commissioned. This was designed and built by Indian scientists and engineers. It was using natural uranium as fuel and heavy water as moderator. The reactor was used for studying new reactor concepts and components. As the core design could be varied, it had a very complicated control system with many automatic checks and safety devices. The reactor was decommissioned in 1984.

In mid-1972 PURNIMA, a zero energy fast reactor, was put up for experimentation in fast reactor physics. The plutonium oxide fuel elements for this reactor were fabricated in glove boxes in a special fabrication plant at Trombay. Later in 1984, it was modified to PURNIMA II which used uranium-233 fuel. Purnima II is now being modified as Purnima III. A mini pool 30 KW reactor Kamini is also being set up at Kalpakkam, Tamil Nadu.

Dhruva

DHRUVA has been the endeavour of over 300 nuclear experts of BARC. Most of the major components of the reactor such as the reactor vessel, fuelling machine, heat exchangers, coolant, circulating pumps, etc., were fabricated in Indian workshops including the workshops of BARC.

The reactor serves as a tool for research in frontier areas of nuclear science and technology and is meant for producing a number of radioisotopes of high specific activity. The reactor provides engineering facilities for testing of prototype power reactor fuel elements under simulated power reactor operating conditions. The irradiation behaviour of fuel elements can be studied with two engineering loops provided inside the reactor core.

Furthering the programme of research in physics, chemistry, activation analysis and biology is another major objective of DHRUVA. A number of built-in-feature of the reactor provide suitable neutron beams to carry out experimental research in nuclear and low temperature solid state physics, material sciences, etc.

A number of beam holes distributed inside and around the peripheral regions of the reactor provide access to thermal and cold neutron flux beams for irradiation purposes.

The reactor has been designed to produce a maximum thermal power of

100 MW. It has a vertical core and is fuelled with aluminium clad metallic natural uranium fuel clusters.

Heavy water is used as the primary coolant to cool the fuel elements in a recirculation circuit and also as moderator and reflector. The reactor core is contained in a cylindrical stainless steel reactor vessel or calandria. The main shell of the calandria is 305 cm long and has an internal diameter of 372 cm with a wall thickness of 1.9 cm. Fuel rod coolant channels are arranged inside this main shell. The fuel rod is 305 cm long and is in the form of seven road clusters inside an aluminium coolant tube which in turn is placed inside a zircalloy guide tube. With a diameter of 1.27 cm the uranium is clad with 1 mm thick aluminium. The guide tube has an internal diameter of 7.5 cm with a wall thickness of 1 mm.

The calandria is kept vertically inside a concrete reactor vault with stainless steel lining. The calandria is closed both at the bottom and top ends by flat plate composite tube sheets. In order to provide adequate radiation shielding, the reactor vault is filled with ordinary water and is surrounded by heavy concrete. At the top of the reactor vault, radiation shielding is provided in the form of an annular shield an end shield and deck plates, which are supported by the vault structure. The coolant outlet is supported by the annular shield.

The reactor vessel provides 146 lattice positions arrangement in a square lattice pitch of 18 cm. Of these 146 positions, two are used for engineering loops and three for corrosion and creep testing facilities. The remaining 141 positions are used for placing coolant channels containing fuel assemblies, for tray rods in which radioisotopes are produced and for neutron absorber rods which are used to shut down the reactor. Under typical operating conditions 129 lattice positions are occupied by fuel assemblies, nine by shutoff rod guide tubes two by tray rods and one by a pneumatic carrier assembly.

In between the coolant channels a set of 20 vertical zircalloy tubes of 2.3 cm inner diameter and 1 mm wall thickness are located in the central region of the reactor core. A solution containing a strong neutron absorbing material can be pumped into the 20 tubes which constitute the emergency reactor shut down system.

The space inside the calandria between the coolant assemblies is filled with heavy water which acts as neutron moderator to slow down the fast neutrons release in fission. In a thermal reactor neutron moderation is essential, to enhance the fission reaction rate and to sustain a steady rate of fission chain reaction and energy release. The heavy water in the peripheral region close to the calandria and away from the outermost fuel channels, called reflector, helps in reducing the size of the reactor core by effectively reflecting the neutrons leaking from the reactor core. DHRUVA has a 60 cm thick radial reflector around the core, a 32 cm thick reflector at the bottom and a 30 cm thick reflector at the top of the core.

DHRUVA employs heavy water as the primary coolant. The heat produced as a result of fission in the fuel rods is removed by heavy water entering the coolant channels at the bottom. The hot heavy water coolant from the reactor then passes through primary heat exchangers (PHEX) and transfers heat to the demineralized process water. The coolant heavy water and the demineralized water are circulated in closed circuits. While the cooled heavy water returned to the reactor, the hot demineralized process water circulates through secondary heat exchangers where its heat energy is removed by the sea water. The hot sea water is then discharged into the sea. The reactor power is regulated by controlled adjustment of heavy water level in the reactor vessel.

Like other modern nuclear reactors, redundancy has been built into DHRUVA to ensure safety in abnormal and even unlikely conditions.

DHRUVA is equipped with primary and secondary shutdown systems. The primary shutdown device enables fast shutdown of the reactor by fast insertion of nine shutoff rods made of neutron absorbing cadmium into the reactor core. As a secondary shutdown device the moderator is drained out the reactor vessel by gravity. This is accomplished by automatic opening of the dump valves located on the heavy water moderator piping below reactor vessel. In the unlikely event of the shutoff rod system failure, a liquid neutron poison can be rapidly injected into the 20 liquid poison tubes located in the central region of the reactor core. These liquid poison tubes constitute the emergency reactor shutdown system.

The safe operation of the reactor is ensured by monitoring and controlling relevant process parameters through extensive instrumentation. The parameters include neutron flux level coolant flow rate, coolant temperature, pressure, etc. Changes in any of the important parameters beyond the predetermined, permissible ranges lead to an automatic shut down of the reactor. All vital instrumentation for the protection of the reactor is triplicated for enhancing safety and reliability.

In the event of a power failure, although the reactor will automatically shut itself down, the fuel needs cooling for an extended period of time owing to the heat generation from the radioactive decay of fission products in the irradiated fuel rods. The heat generation immediately after reactor shutdown is of the order of 10 per cent of the operating power level amounting to 10 MW. In order to prevent any fuel damaged, uninterrupted emergency cooling is provided at a reduced rate by means of auxiliary coolant pumps driven by electric motors operating on emergency power supply. In case the emergency power supply also fails, water turbines driven by demineralized process water stored in an overhead storage tank automatically take over running the auxiliary coolant pumps to maintain coolant circulation. It can be seen that adequate safety provisions have been incorporated in the reactor design for ensuring that in the event of an abnormality in any of the important parameters, the reactor is automatically shut down and uninterrupted cooling of the reactor fuel is ensured in order to prevent any of the radioactive material inside the fuel rods from coming out of the aluminium sheath due to overheating.

Fresh fuel assemblies loaded into the reactor have to be removed after the scheduled irradiation. The fueling machine has been designed to carry out "on power" fuelling operations. Irradiated fuel discharged from the reactor requires special handling. Fuel assemblies discharged from the reactor are transferred through water-filled trenches to a storage pool where they are canned and stored. The canned fuel assemblies are eventually sent in lead-shielded casks to the fuel reprocessing plant.

All radioactive wastes which are small in quantity are carefully collected in an underground concrete vault where different types of effluents are stored in separate compartments. The waste material is carefully handled and subsequently treated in the effluent treatment plant so that no significant radioactive or toxic material is released to the environment.

The ventilation system maintains adequate pressure differences so that air always passes from region of lower radioactivity to the regions of higher activity in a single pass system. Air from the reactor and spent fuel storage buildings is finally exhausted through high efficiency filters to remove all particulate matter before the air is discharged through a 100 m high stack. In case the need arises, the air is also passed through special filters with the help of an emergency ventilation system for ensuring that radioactivity is not released into the atmosphere.

The research facilities provided for two engineering loops which could be used to investigate the performance of prototype fuel elements and materials under simulated operating conditions in a power reactor. The larger facility has a diameter of 15 cm and a maximum thermal neutron flux of 140 trillion neutrons per sq cm per second. The smaller one of 10 cm diameter has a maximum thermal neutron flux of 150 trillion neutrons per sq cm per second. The in-core pressure tubes of both the loops are made of zircalloy. Fuel elements and materials for testing are handled with the help of a second fuelling machine. The heat generated in loops is removed by light water in an independent circuit.

A number of horizontal beam tubes distributed around the reactor core provide access to high neutron fluxes for beam research and irradiation experiments. Two of them are radial beam tubes of 30 cm diameter. Besides, there are four radial and four tangential beam tubes of 10 cm diameter each. The tangential beam tubes provide thermal neutron beams having low background of gamma radiation and fast neutrons.

A 30 cm diameter beam tube placed at a slightly off-radial position is used for inserting a liquid methane moderator maintained at about—160° Celsius to provide very low energy 'cold' neutrons, which have an average energy of about 0.01 electron-volt. The average neutron energy in the reactor core is about 0.03 electron-volt. Two evacuated tubes made of rectangular glass elements coated with nickle and facing the cold source guide the low energy neutrons to a guide tube laboratory adjoining the reactor building.

Another 30 cm diameter radial beam tube is used to place a block of thermally insulated graphite exposed to the neutrons and gamma rays in the peripheral region of the core. Nuclear heating due to gamma rays and neutrons hitting the graphite block maintains its temperature at about 1,325° Celsius. The neutrons emerging from the graphite have an average energy of about 0.1 electron volt. Two 10 cm diameter beam tubes facing the hot graphite on either side at an angle of 30 degrees provide hot neutron beams.

There are two 'through tubes' at two different heights passing from one side of the reactor to the other along a chord of the cross section of the calandria. At the centre of the lower tube there is a compartment of heavy water, which acts as a secondary source of scattered neutrons. The lower through tube is used for neutron research. At both ends of the upper through tube, "self-serve" facilities are provided to irradiate ore loaded into a carrier tube which is mechanically pushed into the reactor core. After irradiation the samples are withdrawn and allowed to fall into a shielded receptacle.

A pneumatic carrier facility is provided for short time irradiation of samples. Using compressed air, the sample to be irradiated is sent from and received back in the laboratory outside the reactor building through a pipe passing through the reactor. This facility is useful in the study of short lived fission and activation products.

For conducting experiments with the neutron beams, a number of microprocessor controlled neutron spectrometers based on new experimental techniques are set up around the reactor inside the reactor building and in the guide tube laboratory. The research facilities include systems to maintain the samples at different conditions. These include liquid helium cryostats, superconducting magnets, high pressure anvils and high temperature furnaces.

DHRUVA enables large-scale production of radioisotopes with high specific activities. Samples are irradiated in specially designed tray rods. A tray rod can hold 72 capsules of 2.2 cm diameter and 7.5 cm length containing samples for irradiation. The tray rods are installed in fuel channels as required and are cooled by heavy water. The "on-power" fuelling machine is used for loading and unloading of the tray rods. The tray rods in DHRUVA permit enhanced production of a variety of radioisotopes used in medicine such as iodine-131 chromium-51 and molybdenum-99 so that the increasing demand for these isotopes in medical diagnosis and therapy can be met. Iodine-125, an important radioisotope used in radioimmunoassay (which is at present being imported), is being produced in adequate quantities in DHRUVA. Iridium-192 with high specific activity, required for the fabrication of intense gamma ray source used in compact radiography cameras, can also be produced with the high neutron flux in DHRUVA.

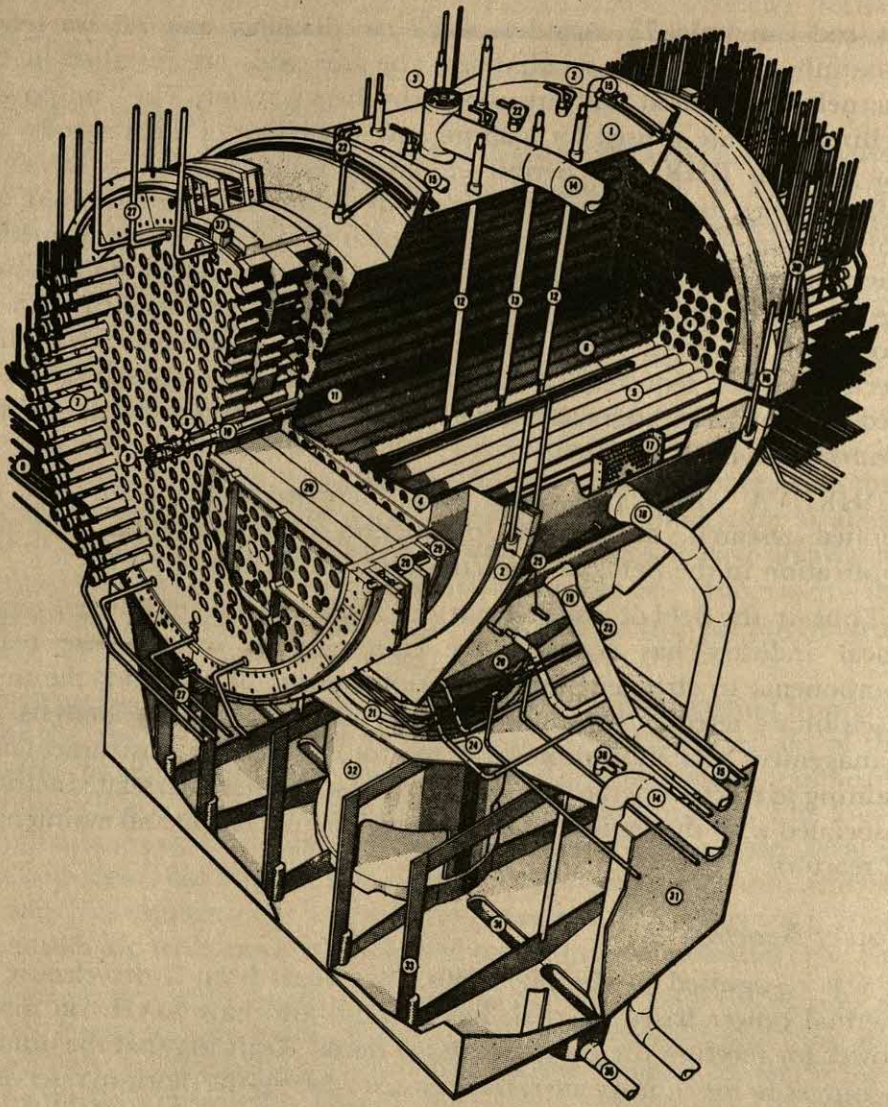
DHRUVA with its facilities gives increased impetus to basic and applied research, and to the production of radioisotopes and their application in the fields of medicine, agriculture and industry.

Thus, in the field of research reactors, India today is entirely self-reliant. Local industry has acquired the capability to manufacture reactor components to stringent nuclear specifications. In addition, the multi-disciplinary research centre at Trombay undertakes safety analysis, fuel management, radiation protection, reactor engineering, instrumentation, training to reactor operators and a whole host of other interrelated activities associated with the setting up and trouple-free operation and maintenance of reactors.

Power Reactors

It was recognized in the late 1950s, that apart from hydro-electric and thermal power based on coal, India would also have to rely on nuclear power for meeting the growing energy needs. Realizing that the uranium resources in the country are rather limited whereas the thorium reserves are the world's largest, a three stage nuclear fuel cycle strategy was laid down in 1954. The first stage reactors are neutral uranium fuelled producing power and by-product plutonium, the second stage reactors would be using plutonium as well as uranium-233 from thorium in the blanket and third stage breeder reactors would be based on self-sustaining thorium-uranium-233 cycle.

For putting up India's first power station, the Tarapur site near Bombay in western India was chosen in 1958 after a comprehensive survey of a number of possible sites all over the country. Although Indian engineers could have undertaken the design and construction of this station without any foreign collaboration, this would have taken a much longer time

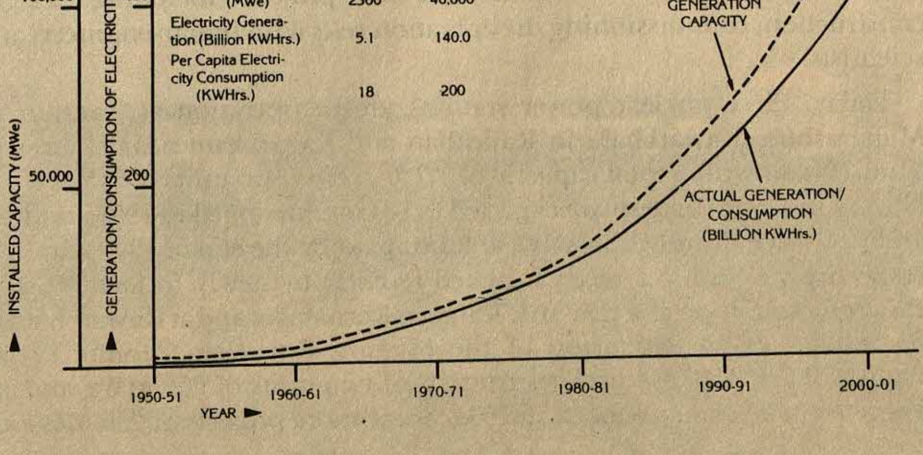


A diagrammatic view of reactor

1 CALANDRIA SHELL
2 STIFFENER RING
3 PRESSURE RELIEF DEVICE
4 TUBE SHEET
5 CALANDRIA TUBES
6 COOLANT TUBES
7 END FITTINGS
8 FEEDER PIPES
9 SEALING PLUG
10 SHIELDING PLUG
11 FUEL
12 ADJUSTER FLOW TUBE
13 ADJUSTER FLOW TUBE
14 HELIUM BALANCE LINE
15 HELIUM PURGE LINE
16 CALANDRIA HANGERS
17 OUTLET MANIFOLD
18 MODERATOR OUTLET
19 MODERATOR INLET
20 TRANSITION SECTION
21 EXPANSION JOINT
22 CALANDRIA SPRAY COOLING
23 DUMP BOX SPRAY COOLING
24 TRANSITION SECTION SPRAY COOLING
25 LEVEL INDICATING INLETS
26 END SHIELD
27 END SHIELD COOLING PIPES
28 END SHIELD RING
29 THERMAL SHIELD BLOCK
30 END SHIELD HANGERS
31 DUMP TANK
32 SHIELDING AND STIFFENER STRUCTURE
33 STIFFENERS
34 DRAIN SLOTS
35 DUMP TANK OUTLET
36 DUMP TANK AND EXPANSION JOINT SPRAY COOLING
37 END SHIELD KEY BLOCK

involving the construction of a prototype station first. To bring nuclear power to the country without delay and to give an opportunity to Indian technical personnel to acquire experience in building and operating a nuclear power station, a tried-out system was brought to begin with. Two boiling water reactors (BWR) of 200 MWe each were purchased from USA in 1964 as a turn-key project, but with maximum participation of Indian personnel in all stages of design, construction, testing and training in operations. Practically all the nuclear/conventional equipment and the fuel elements for this station came from the USA and the station went into commercial operation in late 1969. However, since 1970 the enriched uranium fuel elements for the station are being fabricated in India based on imported hexafluoride. As the Tarapur reactors are amongst the earliest BWRs, several modifications have been progressively carried out based on operational experience to ease operation and maintenance of equipment, reduce personnel radiation exposures, minimise radioactive discharges to the environment and improve reliability and overall performance of the station.

In 1960 it was decided that the first stage natural uranium reactors would be of the heavy water type. These reactors would enable the maximum



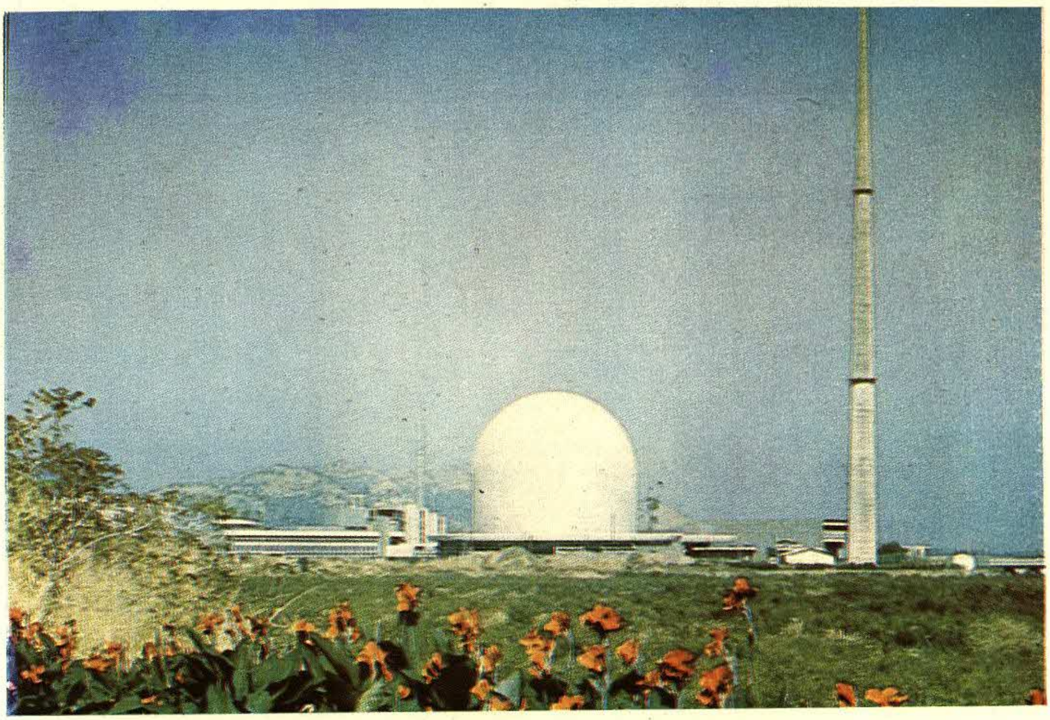
PAST AND PROJECTED GROWTH OF ELECTRIC POWER GENERATION CAPACITY AND ACTUAL GENERATION/CONSUMPTION OF ELECTRIC POWER IN INDIA

	1950-51	1983-84
Installed Capacity (MWe)	2300	40,000
Electricity Generation (Billion KWHrs.)	5.1	140.0
Per Capita Electricity Consumption (KWHrs.)	18	200

utilization of the country's limited uranium reserves. By 1962 it was decided that the second atomic power station would be located near Kota in the state of Rajasthan and that the two 220 MW reactors would be based on a Canadian design which at that time was not considered as proven. Canada was responsible for the design and supply of major equipment for the first unit while India took up the responsibility for construction and installation activities. Right from the start of this project, efforts were made to manufacture as many components as possible in India. While major equipment, both nuclear and conventional, for the first unit had necessarily to be imported, part manufacture of some of the major component was undertaken in India. Many items of auxiliary equipment were supplied from Indian sources and half the initial fuel charges was also manufactured in India in addition, the instrumentation and control system was to a large extent assembled in India. Efforts at indigenization of components were intensified for the second unit and major nuclear components were manufactured in India. Thus, the Rajasthan station opened up opportunities for many Indian industries to enter the nuclear power field and develop sophisticated technologies indigenously. Some of the nuclear equipment manufactured in the country for the second unit include the reactor vessel (calandria), end shields, dump tank, shield tank, steam generators, fuelling machines sealing and shield plugs, etc.

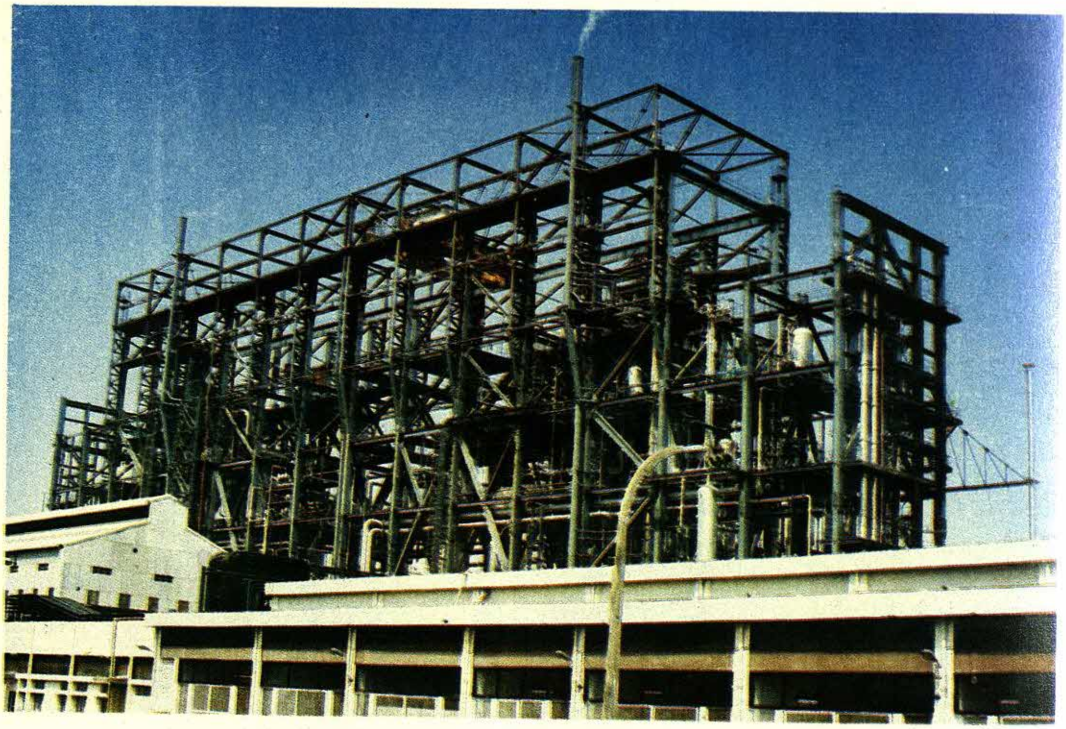
The third atomic power station near Madras which consists of two units of 235 MW each has been commissioned. Though these reactors are similar to the Rajasthan units, several design modifications have been introduced for reasons of economy and due to special conditions at the site. Some of the modified features include pre-stressed concrete reactor containment building, stainless steel and shields, submarine tunnel for drawing cooling water from the sea and an indoor switchyard. The Madras station marks the coming of age of the Indian atomic energy programme, as full responsibility for the execution of the project, including design, construction, commissioning the operation rests with Indian engineers and scientists.

Today, three nuclear power stations are in operation at Tarapur in Maharashtra, Rawatbhata in Rajasthan and Kalpakkam near Madras in Tamil Nadu with a total capacity of 1,730 MWe. Two units of 235 MWe at Narora in Uttar Pradesh are expected to be commissioned in 1988 and 1989 and two more units of 235 MWe at Kakrapara by the end of 1990 and 1991 respectively. Work has been initiated recently by newly formed Nuclear Power Corporation at a new site, Kaiga in Karnataka, and at Rawatbhata in Rajasthan, as an expansion of the existing Rajasthan Atomic Power Station. Each of these projects consists of two units of 235 MWe and are expected to be commissioned in 1994. Some more projects of 235 MWe are

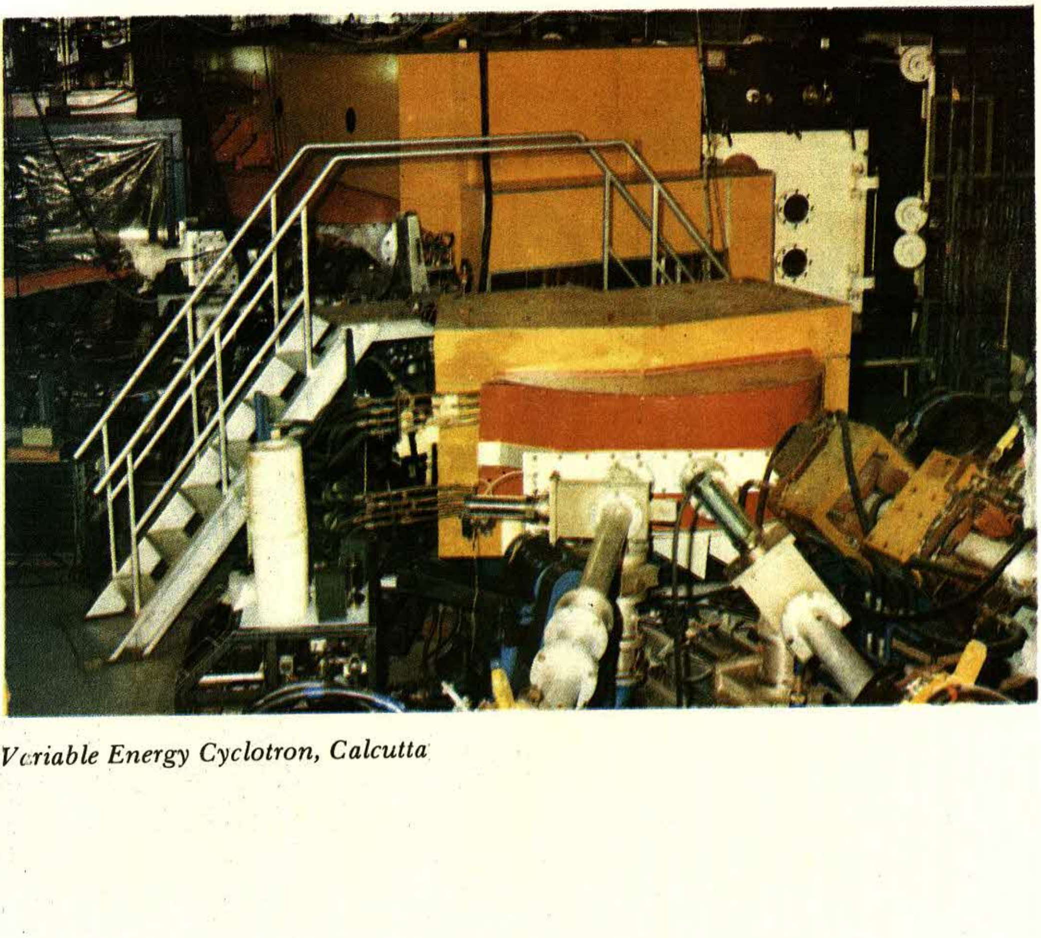


Tarapur Atomic Power Station, Trombay

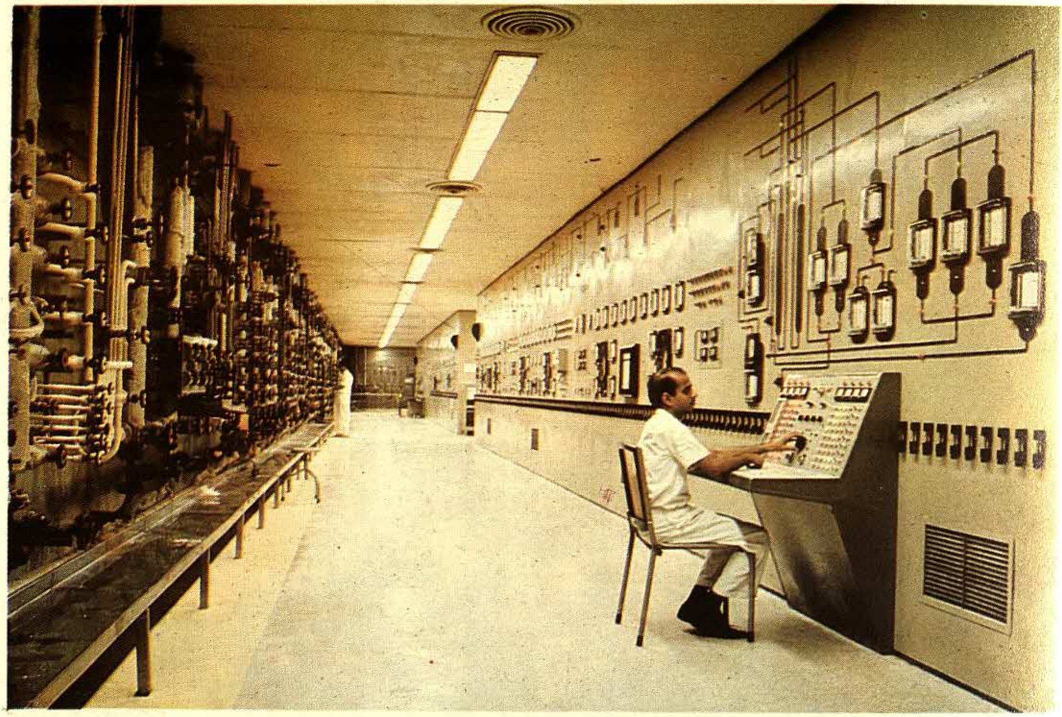
Exterior View of Rajasthan Atomic Power Station (RAPS), Kota



Heavy Water Plant at Thal

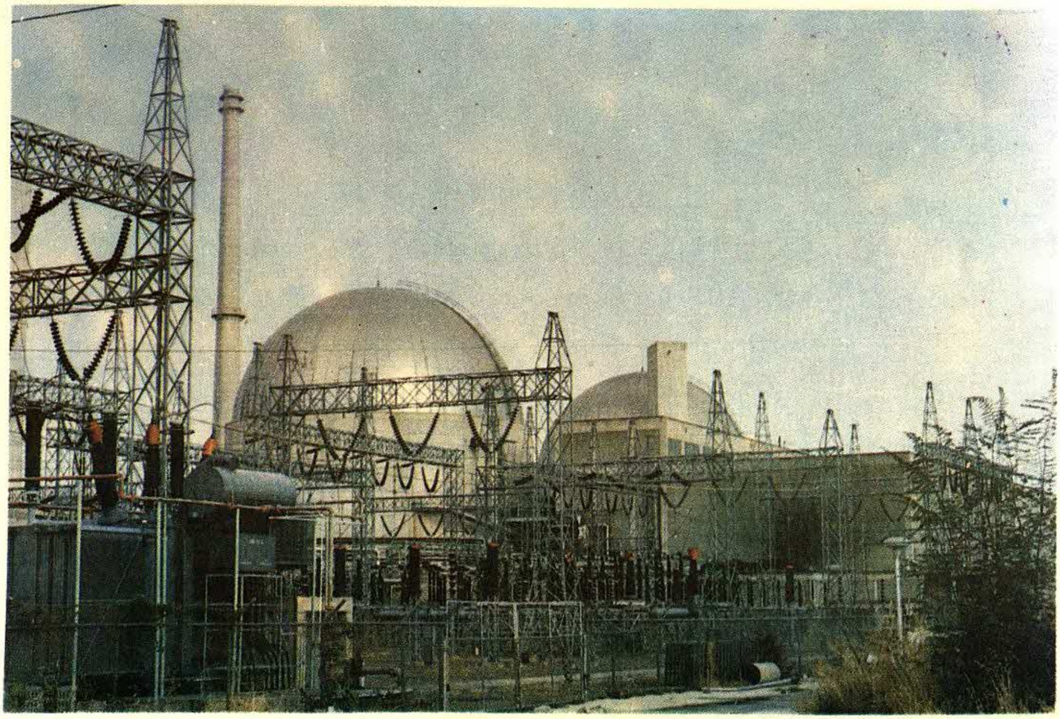


Variable Energy Cyclotron, Calcutta



Control Room of Tarapur Atomic Power Plant

FBTR at IGCAR



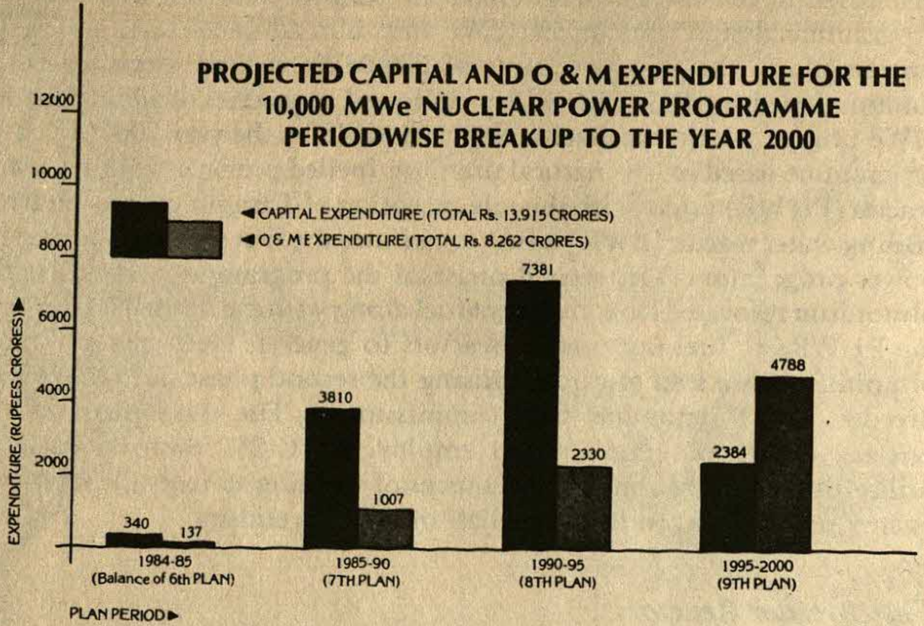
visualised in the 15-year programme. In parallel with this MWe reactor programme, design work on 500 MWe units is in advanced stage and as per current plans, the first two units of 500 MWe size are expected to be commissioned in 1995. This will be followed by a series of additional 500 MWe units to attain a capacity of 10,000 MWe by the year 2000 AD. The programme based on the natural uranium fuelled pressurised heavy water reactor (PHWR) units (with the sole exception of Tarapur plant which has boiling water reactor [BWR] units) constitutes the first phase of the nuclear power programme. The second phase of the programme will utilize the plutonium recovered from the spent fuel along with the unused U-238 from the PHWRs to fuel fast breeder reactors to generate electricity and more plutonium. As a step towards realising the second phase, a 15 MWe Fast Breeder Test Reactor has been commissioned. The third phase of the nuclear power programme will employ the U-233 thorium cycle to utilize the country's abundant resources of thorium to meet the country's energy requirement in the latter half of the 21st century.

Fast Breeder Reactors

The Fast Breeder Test Reactor (FBTR) with a design capacity of 40 MW thermal and 13 MW electrical power attained its first criticality on October 18, 1985, at the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam in Tamil Nadu. The commissioning of FBTR marks the commencement of the second phase of India's nuclear power programme. It is very significant that the construction and commissioning of this advanced reactor has been mostly an indigenous effort. The design and fabrication of a new plutonium based fuel for the reactor, the harnessing of sodium technology and the manufacture of most of the critical components within the country are among the major achievements.

The nuclear chain reaction in the uranium fuel in a thermal reactor is sustained by slowing down the neutrons by a moderator. On the other hand in an FBR the chain reaction is sustained by fast neutrons. When fission is induced by fast neutrons, the number of neutrons released per fission is more compared to that in thermal reactor. The extra neutrons are available for absorption in uranium-238 to transform it to fissile plutonium-239.

In a nuclear reactor (fuelled with uranium or plutonium and uranium) heat is produced through the fission of U-235 and Pu-239 nuclei, and at the same time the nonfissile uranium-238 gets converted to plutonium through neutron capture and radioactive decay. The efficiency of the conversion is judged by the ratio of fresh fuel produced to fuel consumed. In a pressurised heavy water reactor (PHWR) this ratio is about 0.8 whereas it is more than one (1.2 to 1.3) in a typical large size FBR on account of the better neutron

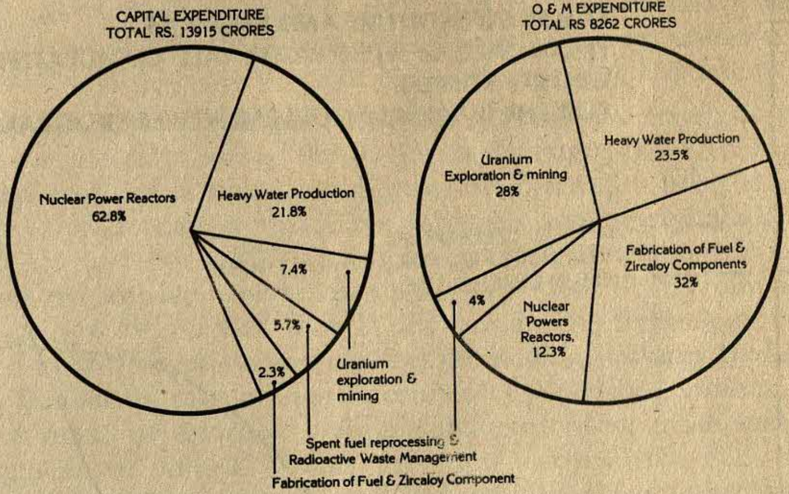


PROJECTED CAPITAL AND O & M EXPENDITURE FOR THE 10,000 MWe NUCLEAR POWER PROGRAMME PERIODWISE BREAKUP TO THE YEAR 2000

yield and economy. Thus, in producing electricity, through the operation of FBRs, the total energy potential in natural uranium can be much better harnessed. In a thermal reactor typically only about 1-2 per cent of the natural uranium is utilized whereas in FBRs the utilization is increased to 60 to 70 times.

In the construction of an FBR it is necessary to exclude all materials of low atomic weight which slow down the neutrons. Therefore, water cannot be used as a coolant. Considering the nuclear and heat transfer properties of various possible coolants, sodium has been universally accepted as the coolant for FBRs. Sodium melts at 98°C and boils at 880°C at normal atmospheric pressure. Therefore, to get a high coolant outlet temperature from the reactor the sodium is not required to be pressurised. The heat generated in an FBR core is removed by primary sodium, which in turn transfers it to secondary sodium. The secondary sodium transfers heat to water (in the steam generator) to provide high temperature high pressure steam. The temperature of the primary sodium entering the reactor is typically about 380° to 400°C, and it leaves at 530° to 550° The steam conditions are in general 480° to 500°C and 160 to 180 kg/sq. cm. Due to the higher steam temperature and pressure, the efficiency of converting heat into electricity is typically about 40 per cent in FBRs compared to 30 to 32 per cent in water cooled reactors. Due to the high thermal efficiency of FBRs the number of atoms fissioned to produce a unit of electricity is less

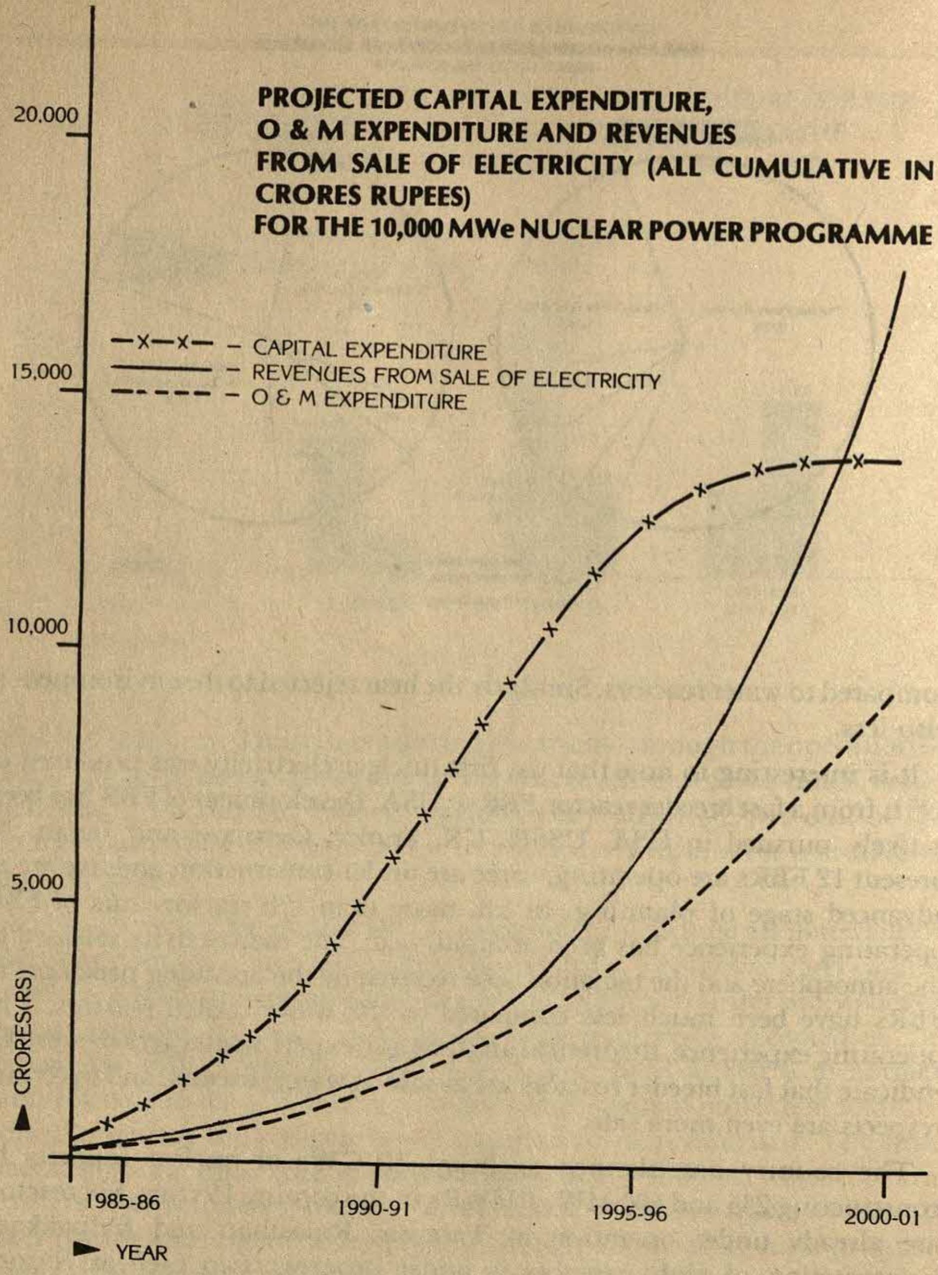
CAPITAL AND O & M EXPENDITURE FOR THE 10,000 MWe NUCLEAR POWER PROGRAMME: SECTORWISE BREAK-UP TO THE YEAR 2000



compared to water reactors. Similarly the heat rejected to the environment is also less.

It is interesting to note that the first nuclear electricity was produced in 1951, from a fast breeder reactor FBR-1, USA. Development of FBR has been actively pursued in USA, USSR, UK, France, Germany and Japan. At present 12 FBRs are operating, three are under construction and five are in advanced stage of planning. In all, more than 170 reactor-years of FBR operating experience has been accumulated. The radioactivity released to the atmosphere and the radiation dose received by the operating personnel in FBRs have been much less compared to the water cooled reactors. The operating experience, theoretical analysis and experiments carried out so far indicate that fast breeder reactors are as safe as water reactors, and in certain respects are even more safe.

The country has planned to instal 10 GWe of nuclear capacity by constructing 235 and 500 MWe PHWRs in the coming 15 years. Six reactors are already under operation at Tarapur, Rajasthan and Kalpakkam. Construction of eight reactors is under progress, two each at Narora, Kakrapara, Kaiga and Kota. With the construction and successful commissioning of the two units of MAPS (Kalpakkam), which is entirely an indigenous effort, the technology can be considered to have matured with respect to the PHWRs in India. Heavy water is being produced within the country. All the fuel is being fabricated at the Nuclear Fuel Complex (NFC), Hyderabad.



PROJECTED CAPITAL EXPENDITURE, O & M EXPENDITURE AND REVENUES FROM SALE OF ELECTRICITY (ALL CUMULATIVE IN CRORES RUPEES) FOR THE 10,000 MWe NUCLEAR POWER PROGRAMME

The important role of FBRs was recognized very early in the Indian atomic energy programme, and studies on FBRs had been initiated in BARC in the 1960s. In 1971 the Reactor Research Centre (RRC), now named as Indira Gandhi Centre for Atomic Research (IGCAR), was established at Kalpakkam to develop the indigenous capability in the field of FBRs. The main facility at this Centre is the FBTR, a sodium cooled, loop-type, plutonium-fuelled, power generating plant. The other facilities at IGCAR, include basic research facilities in the field of materials of interest to FBRs and a Reactor Engineering Laboratory and the technology of reprocessing fast reactor fuel is being developed in the Reprocessing Laboratory.

FBTR is based on the design of the Rapsodie reactor of France which was operated successfully during 1967-83. The basic design of the French reactor has been modified in order to indigenise the fuel and blanket materials, increase safety, reduce the operational problems, and the capital cost of the reactor. The fuel used in FBTR is a mixed carbide of plutonium and natural uranium, the proportion of the latter being 30 per cent. Such a composition is being used for the first time in the world. The technology for the fabrication of the fuel was developed at the Radiometallurgy Division of BARC. Similar size reactors in other countries use enriched uranium in the form of metal or enriched uranium and plutonium oxide fuel. The development of mixed carbide fuel was carried out due to the nonavailability of enriched uranium. The carbide fuel has higher breeding ratio due to its higher density and thermal conductivity. Steam generators have been added in FBTR in order to produce steam and to run the turbine connected to the grid. Such a provision was not existing in the French reactor. The experience of a complete plant will be very useful in the design of a prototype fast breeder reactor.

One hundred and fifty tonnes of sodium was required for FBTR. The sodium has been manufactured indigenously and was purified at IGCAR to the nuclear grade. The permissible impurity limits in sodium are only a few parts per million of oxygen, carbon, hydrogen and calcium. A special purification rig was designed and built in the Reactor Engineering Laboratory and the sodium was purified by filtering and cold trapping to the required specification.

The manufacturing specification for the FBTR components are much stricter than the thermal reactors due to high operating temperatures, sodium coolant and fast neutron exposure. Thanks to the low operating pressure with sodium the stainless steel parts are relatively thin-walled. Control of dimensions during welding is one of the challenging tasks in manufacturing of the components. Though a base of nuclear quality awareness was created with the construction of PHWRs, the stringent requirements and lack of experience in the manufacture of thin stainless steel parts necessitated transfer of manufacturing technology to the Indian industries from their counterparts in France. The emphasis during the construction of FBTR was on maximum indigenization. Initially Indian industry was hesitant in accepting the manufacture of the components on account of the high quality standards, prototype nature of the manufacture and the likely financial risks. However, with persuasion, they have responded splendidly. The key components, namely the reactor vessel, rotatingplugs, control rod, drive mechanisms, sodium pumps, intermediate heat exchangers, steam generators, fuel handling machines, computers, control and instrumentation packages, ward leonard drives and core subassemblies have all been manufactured within the country. The manufacture of stainless steel components require separate areas for the fabrication nuclear clean hall for assembly and surface treatment facility for cleaning of the components. The welders have to undergo rigorous training in order to produce stringent radiographic quality welds. The important achievements of the Indian industry include special forming operations like the pull outs 'T' bend, rolling of shells to stringent dimensional tolerances, accurate machining of large size flanges, plates and assemblies, helium leak testing and optical alignment checks. For the critical components a large number of test coupons were provided to check the properties by destructive testing. The indigenous content of FBTR is as high as 78 per cent. This has been possible mainly due to the active participation of the Indian industries.

The FBTR will be utilized for carrying out irradiation experiments to develop the fuel cycle of the fast reactors. Potential fuel materials like carbide oxide and nitride will be irradiated in FBTR to burn-ups of 100 MWd/kg in order to optimise the design parameters. The behaviour of fuel at high temperature under the high neutron flux will be investigated, though post-irradiation examination of the fuel pins discharged from FBTR. A special radio-metallurgy laboratory has been annexed at FBTR for this purpose and has facilities to measure the fission gas release, fuel pin dimensional changes measurements of the thermal conductivity after irradiation, etc. Structural materials like stainless steel 316 with various compositions and different metallurgical conditions will also be irradiated in special experiments to find out the changes in the properties due to high neutron flux, temperature and sodium. The properties after irradiations will be tested in the hot cells. The main challenging task is to reduce the void swelling of the stainless steels, which at present limits the fuel burn-up in fast breeder reactors.

The next step after FBTR is to design and construct a Prototype Fast Breeder Reactor (PFBR) of 500 MWe capacity, The 500 MWe size of reactor has been selected to match the size of coal fired thermal power stations and PHWRs. The technology developed in the industry for the conventional equipment like TG set, condensers, switchgear, transformers, etc., can be used for PFBR without any special efforts for the design and development. The 500 MWe size will also reduce the specific capital cost and at least a few such reactors can be constructed before going in for the next size reactor in the range of 1,000 to 1,200 MWe.

The PFBR will be cooled by sodium as in the case of FBTR but it will use the pool-type concept which is more favoured in recent times due to better safety and more operating experience. The four primary pumps, eight intermediate heat exchangers are immersed in the main vessel. The four secondary sodium loops remove heat from the primary circuit and transfer it to the water in one though type, straight tube, modular steam generators. The fuel handing is carried out under shutdown conditions with the help of a straight pull. The vessels transfer machine and inclined ramps. The main materials for construction of the reactor will be austenitic stainless steels 316 and 304 except for the steam generators which will use ferritic steel. The components working at low temperature in an argon atmosphere will be constructed from boiler quality carbon steel. The components manufacturing specifications are stricter than the presently used codes for thermal reactors. Some of the components like the main vessel, its double envelope, inner vessel, core support structure and roof slab cannot be transported in single pieces after completion in the manufacturer's place. Therefore, these components will have to be manufactured partly in the manufacturer's shop and assembled in the site workshop mainly by welding. The diameter of the main vessel is in the range of 14 to 15 m and height about 15 m and the vessel weighs 150 tonnes. The roof slab is an annular disk of 2.5 m in thickness, 18 to 19 m outer diameter and 8 m inner diameter. The manufacture of sodium pumps with flow of 2t/s and a head of about 7 kg/sq cm involves radiographic quality stainless steel castings (of about 1m in diameter) for the impellers and diffusers, welding, machining, heat treatment of long shaft about 8 m in length and balancing of the rotating parts very accurately. The intermediate heat exchangers are 10 m in length and are of shell and tube concept. The manufacturing involves the bending of the tubes, accurate drilling of tube sheets, welding of tubes to tube sheets. Manufacture of steam generators is a challenging task not only to the Indian industry but also to all industries the world over. A very small leak of high pressure water/steam in the low pressure sodium can start a violent sodium-water reaction and affect the plant availability. Experience in the developed countries indicates that the success of fast breeder reactors depends on the success of steam generator. The welding of the tubes to the tube sheets, forming of pullouts on the shells, rigorous nondestructive testing with radiography, controlled heat treatment and assembly of the long tube in the shells are all parts of this technology. The overall length of the steam generator will be about 25 m. The main sodium pipes of the secondary circuit have to be fabricated from stainless steel plates with minimum welds and shrinkages.

Nuclear Power Industry

Now, the emphasis on indigenisation in the country's atomic energy programme is gradually leading to the creation of a modest nuclear component manufacturing capability in the industry. This is happening largely through technical assistance provided to the industry by the Department of Atomic Energy (DAE) as also through transfer of technology developed in the Department's R&D institutions like the Bhabha Atomic Research Centre (BARC), Bombay. Major components such as the reactor vessels, end shield, thermal shield plants, steam generator and fuelling machines for the Pressurised Heavy Water Reactor in Rajasthan Atomic Power Station (RAPS) and in Madras Atomic Power Station (MAPS), Kalpakkam, have been fabricated by Indian engineers.

The Indian industry has taken up the manufacture of large and complex components for nuclear stations for the first time and it is creditable that the very third atomic station of the country at MAPS has a 90% indigenous content. As against this, indigenous content in the first and second unit of RAPS was only 55% and 70%.

The order for steam generator constituted the first important one placed on an Indian supplier for complete manufacture of major equipment in the nuclear portion of the plant. Larsen and Toubro (L and T) made the steam generator for the second unit of RAPS, which is designed for the primary flow of heavy water, with ordinary water flowing in the secondary side, and raising steam. The design of these generators differs from that of conventional ones in several respects largely due to the use of heavy water as the primary fluid.

L and T has also made the second reactor vessel, Calandria, which forms the heart of the nuclear power reactor and contains the fuel and the moderator (heavy water). The fabrication of Calandria requires highly sophisticated workshop facilities and equally skilled personnel. Fabrication at every stage demands strict adherence to stringent pressure vessel code, machining to close tolerances and high quality of heat treatment.

It is worth mentioning that during 1987 there was not a single failure in any of the indigenous fuel bundles supplied to Indian atomic reactors. The defect rate was just 0.10% in contrast to 0.28% encountered in the fuel bundles imported originally for the Rajasthan reactors.

The fuel bundles and zircalloy components are made at the public sector Nuclear Fuel Complex, Hyderabad. Zircalloy is required to sheath the uranium oxide pellets before it is put inside the reactor. The present capacity of the plant is 90 tonnes of uranium fuel which will be doubled by the end of this year. The capacity for fabrication of zircalloy will be also increased from the present 35 tonnes to 50 tonnes per year. NFC has also set up a fabrication facility to make thorium oxide pellets and other materials required as initial fuel and replacement fuel for the fast breeder reactors to come up by the end of the century.

Another indigenous nuclear equipment is the fuelling machine used for loading and unloading fuel at RAPS and MAPS. The equipment development is of significant importance since heavy water moderated and cooled natural uranium CANDU reactors required refuelling to be done as a normal operation with the reactor running at power. To operate under such demanding conditions, the fuelling machine components have to be manufactured to an extremely high degree precision so that reliability in on-power refuelling is assured.

Thougn most of the components were fabricated at the Cooper Engineering Works, certain critical components such as the pre-machined and welded magazine rotor and finish machined ram housing requiring special facilities and manufacturing skill were fabricated at the central workshop of BARC.

Sealants required for the nuclear industry are being made under a programme of the Power Projects Engineering Division (PPED) of the DAE and the Chemistry Division of BARC in collaboration with the National Chemical Laboratory, Pune. The sealants have to be of a special type because of the stringent leak-tightness specifications. The traditionally used sealants such as mortars do not guarantee trouble-free performance over an extended period of time.

The only plant in the country producing quality seamless, stainless steel tubes and pipe in a number of grades is the NFC. It produces 3,000 tonnes of these, essentially for the nuclear plants, per year.

Work on end-shield rings, one at either end of the calandria which provide shielding against radiation from the calandria face is done at the Bharat Heavy Electricals Limited, Bhopal. Two other major pieces of equipment fabrication in the country are the calandria and dump tank. While L and T at Powai near Bombay produced the former, dump tank is manufactured at Walchand Industries near Pune. Both these equipment are overdimensional.

As a first step in self-reliance in the second generation liquid metal cooled fast breeder reactor (LMFBR) technology, it was decided to use an indigenous fuel in the 40 MW fast breeder test reactor (FBTR) commissioned in Kalpakkam recently with available natural uranium resources and plutonium.

Keeping this in view, mixed uranium-plutonium monocarbide was recognized is an advance LMFBR fuel because of several attractive features like better thermal conductivity and higher heavy atom density. The combination was 70% plutonium carbide and the rest uranium carbide. The choice of mixed carbide fuel will save the country considerable foreign exchange. Further, with carbide fuel in FBTR, the country will gain experience for the more advanced breeder fuel.

The IGCAR, whose main project is the FBTR, also sustains a fast reactor research and development programme and a number of laboratories and facilities were established there. IGCAR has already established a strong base in sodium technology to cater to the needs for sodium coolants based FBTR. Several static and flowing sodium rings, including a versatile 500 KW loops with all peripherals and test facilities have been set up for testing equipment like fuel sub-assemblies, sodium pumps, heat exchangers, control rod drive mechanisms, special instrumentation, etc. Considerable experience has been gained in sodium purification and sodium fire control. In addition much progress has also been made in other fields of applied and basic research of relevance to a fast breeder reactor programme. An active laboratory for pilot plant work in the development of aqueous and non-aqueous fuel reprocessing techniques has been set up.

The test reactor will provide the experience in the design, construction and operation of liquid metal cooled fast breeder reactors including power generation and serve as an irradiation test bed for the development of fuel, blanket and structural materials. In addition valuable experience will be gained in LMFBR technology pertaining to sodium pumps, sodium heat exchangers, sodium-heated steam generators, fuel handling machines, control rod mechanisms in-core and out-of-core instrumentation, etc.

Rupture disks used for safety in sodium circuits have been completely developed at the centre. A very important aspect of FBTR project is that the construction is entirely indigenous. It is a sodium cooled plutonium fuel loop type fast reactor of 40 MW thermal and 13 MW nominal electrical power. A bold decision was made to fabricate all the major components like the reactor vessel, fuel and reflector sub-assemblies, rotating plugs control rod drive mechanisms, sodium pumps, steam generators, special steam turbine, fuelling machines, central data processing pumps, intermediate heat exchange system and control room panels within the country.

Novel fabrication techniques were also developed. For example, for hot forming of nozzle pull outs of the reactor vessel, further distortion free welding procedure had to be developed. The fabrication and erection of FBTR components has been successfully achieved with the participation of public and private industry. Since the components are being manufactured for the first time in India, the efforts have been of a trail-blazing nature.

The industries that have participated with a major quantum of responsibility in the FBTR project are BHEL, Triveni Structural Electronics Corporation of India Limited, Walchandnagar Industries, and Kirloskars. Nuclear Fuel Complex, Hyderabad, took the responsibility for the manufacture of all parts of the fuel sub-assemblies excluding fuel pins as well as the nickle and steel reflector sub-assemblies. The fuel pins of Indian design are fabricated at BARC.

Plutonium Metallurgy

From the very inception of India's nuclear energy programme, the potential of plutonium for unlocking the huge energy reserve of India's limited uranium resources (estimated at 60,000 tonnes) and abundant thorium resources (estimated at 320,000 tonnes) and, for its peaceful potential as a nuclear reactor fuel offering energy thousand times greater than all available fossil fuels, have been recognised. The advantages of plutonium as a fissile fuel is its high breeding ratio (the number of neutrons produced per neutron absorbed) its high fast fusion cross section, higher energy release lower xenon poisoning and its ability for high fissility in both thermal and fast neutron range apart from its reactor adaptability. Although the separation and analytical procedures for plutonium activity, initially known since the Manhattan Project, was started in 1958, India's spent fuel reprocessing plant for recovery of plutonium was commissioned only in 1964. Our achievements in the development and fabrication of plutonium metal and plutonium bearing metallic and ceramic fuels, as well as our projected ability for utilization of plutonium for generation of nuclear electricity are creditable.

Plutonium metallurgy was introduced in India in 1960, when a group of scientists and technologists at Bhabha Atomic Research Centre (BARC) Trombay, successfully isolated minute beads of this highly fissile metal by calciothermic reduction of plutonium tetrafluoride. Since then, there has been an enormous scale up of production and investigation of this metal, its alloy and compounds. A sophisticated plutonium metallurgy laboratory facility set up in Trombay now manages the production and intensive utilization of plutonium for generation of nuclear power and simultaneous breeding of the fissile materials.

The man-made plutonium metal is developed by the transmutation process of the naturally occurring uranium. Plutonium formation process is a complex series of thermal physico-chemical reaction. It is formed by the successive decay of the uranium isotope when thermal neutrons are bombarded into the mixture in the nuclear reactors during power generation.

During this process nuclear reactors also produce other prominent fissile isotopes of plutonium 240, 241, 242, through successive neutron captures. The spent uranium fuel elements are a mixture of depleted uranium containing 238 and about 7% of 235 in excess, highly radioactive fission fragments and plutonium. The composition and the percentage of presence of the different plutonium radionuclides depend on a variety of factors like the discharge burn-up of fuels, neutron flux and energy spectrum, fuel enrichment moderator to fuel volume ratio, fuel diameter clading materials, the burn-up quantity of fuel, etc. All these factors may vary with different types of reactors. Therefore, the perfection and efficient operation of this process will demand rigorous and sophisticated technological controls on equipments, techniques, processes and instrumentation.

The separation of spent fuels and plutonium in a reprocessing plant, after their appropriate cooling for the shortlived radioactivity to be down, by mechanical and chemical dejacketing from the cladding material, is also a complex process. In this process the spent fuel elements are dissolved in nitric acid and the solution is then subjected to solvent extraction removal of fission products including plutonium in the first stage and uranium in the second stage. The plutonium is further purified by an ion exchange process and obtained a plutonium nitrate. The nitrate solution is converted to plutonium oxide powder through oxidation and direct calcination. This process, although very simple compared to other known methods, has the drawback of contamination and, therefore, requires high purity feed solution. Plutonium oxide powder is the end-product from the reprocessing plant and is stored as chemically stable and easily transportable material.

Much of the metallurgical knowledge for the preparation and separation of plutonium, including the free energy diagrams of oxide and fluoride of plutonium with the thermodynamic data of plutonium halides-reduction reaction is familiar to India.

The technology makes use of the accompanying heat release in large quantities to melt the reaction products and keep them in molten condition long enough for good slag metal separation without the reducing agent forming any intermetallic compound with them. The choice of calcium and the addition of 0.3 mole of iodine to make the reaction more exothermic during the reduction of plutonium tetrafluoride lowers the melting points of the slag.

In the calcium reduction process plutonium tetrafluoride and calcium metal in appropriate proportion are mixed and charged into a high temperature, high-pressure sealed steel bomb purged of all air with argon and the vessel is subjected to resistance or induction heating to about 600° C. The products melt at the controlled heat generated at required speed to avoid cooling or the solidification of the slag on the one hand and the coating of calcium particle with the calcium iodine. The monitoring of the reduction reaction accompanied by a rise in temperature is done by a thermocouple or by noting the drop in the neutron emission from the reactor chamber. Alternatively PuF and finely divided calcium (50% excess) are mixed and pressed into pellets. The pellets are loaded into a calcium flouride crucible and then in a quartz tube. On heating a bright flash shows the initiation of reaction.

The direct calciothermic reduction of dioxide overcomes the drawbacks of fluoride and chloride process namely high neutron emission and hygroscopicity respectively as also the costly halogenation step.

The high toxicity biological behaviour and the fissile properties of plutonium present radiological critically-hazards that necessitate handling of plutonium and in its metallurgy, unlike in other metallurgy technologies. The prevention of particulate matter containing the long acting, high energy alpha ray-emitting and bone seeking plutonium from entering the body of the operator and restriction of its concentrations in air and water within permissible limits are important for safety.

Radiation Standards Laboratory at BARC has developed its own radiation dosimetry standards and related instruments and processes for this purpose. The restriction on the mass of plutonium handled a time automated and remote handling equipment and manipulators, containerization of the plutonium bearing powder and dust to prevent their accumulation on equipments and glove boxes, control on processes, the design and use of inert atmosphere, gloves for handling the metal its carbides and nitrides susceptible to easy oxidation, hydrolysis and pyrophoresis are the safety steps developed and adapted by the Radiometallurgy Division of BARC. Other safety measures against the occurrence of criticality accidents have also been successfully developed with priority over cost and convenience considerations.

The extreme toxicity, the proneness of the metal to oxidise rapidly, the pyrophoricity, the easy and high criticality, etc., make plutonium metallurgy highly technology sensitive and demands high precision controlled, high temperature and pressure-resistant reaction vessels with suitable heat transfer properties that are safe for operation. The choice of inductive heating rather than direct arc or electron beam furnaces is also governed by these factors. The extremely high reactive nature of molten plutonium necessitated the choice of graphite crucibles in preference to tantalum and ceramic crucibles (which can resist or withstand a temperature of only 1,000°C).

The melting of the crucible material and its dissolution with plutonium at high temperature, the cracking of the crucible and contamination of the melt also had to be overcome. The coated tilt or bottom-ouring graphite crucible is thermal shock resistance. Similarly graphite or grey cast-iron, mild steel copper or tantalum moulds are used to withstand the low melting point, high fluidity and density, extremely small volume change on freezing, their low piping shrinkage and porosity characteristics make plutonium casting easier. Although a number of phase transformations within a small range of temperature (cooling) is characteristic of plutonium, it can be avoided by heating the mould against cold-shuts in casting, choice of crucible material and by special designing of the crucible. This will also prevent the adhering and cracking of the mould and the crucible.

The use of similar metallothermic reduction techniques eliminates several costly processes and steps of metal production and its handling in inert atmosphere. The problem of gravity segregation of the plutonium alloy elements is overcome by an aluminothermic reduction of plutonium oxide in a graphite crucible in the presence of excess aluminium and cryolite at around 1,100°C. The reduced plutonium alloy with excess aluminium as slag metal, is recovered by melting the alloy for proper homogenization and recasting in another crucible.

The plutonium metallography facility using glove boxes for mounting, cutting, grinding, polishing and etching of the alloy demands high technological sophistication. This Al-Pu alloy has the advantage of low parasitic thermal neutron absorption, high thermal conductivity, etc., which makes it a good inert carrier for the fissible plutonium. The plutonium metallurgy laboratory at BARC fabricates this alloy using high vacuum melting-casting unit, a high hot high cold, cold hot rolling mill and an annealing furnace, all especially designed indigenously. It uses a picture frame technique to fabricate the sub-assemblies of the roll bonded aluminium-clad Al-Pu fuel plates and alloy elements. These are used as boosters in pressurised heavy water reactor to overcome xenon poisoning following posts shut down start-ups.

The plutonium-beryllium alloys, also used as low flux sources, utilizes interaction of alpha particles from plutonium with beryllium atoms to generate neutrons. It gives good stability of neutron yields and relatively small amount of gamma radiation from the encapsulated metallic cans. The design and composition of the complex containers and the point or pencil sources used for the collaboration of the neutron counters for the start-up of reactor and in the measuring of moisture and hydrocarbons is complicated.

The delta stabilised plutonium alloys are prepared by vacuum induction hearing in coated graphite crucible and cast in graphite moulds. The alloy fuel with high melting point and stabilized low temperature phase, the least allotropic and volume transformations within a wide temperature range must have many metallurgical and mechanical properties such as machinability, castability, turnability, ductility, oxygen resistance, etc. The problems of gravity segregation and negligible solidification shrinkages of the alloy elements are difficult to tackle technologically.

Technology for the fabrication of the ceramic alloyed plutonium dioxide stainless steel-clad fuels for the entire core of 186 fuel pins containing about 25 kg of sintered PuO pellets, using the technology for production of zircalloy-clad uranium was perfected in 1972 at BARC. The designing of the special stainless steel cladding tubes containing the pellets between a pair of axial molybdenum reflectors, the power metallurgy of cold compaction and sintering at 1,600°C argon-hydrogen atmosphere and the radiographic and mass spectrometric helium leak and crack and contamination checking needs careful manipulations using technologically sophisticated instruments in difficult working conditions.

After the abandoning of the pure plutonium oxide as fuel in big reactors, technology for using mixed oxide fuel technology using oxides of uranium and thorium through cold compaction process into pellets and their sintering in controlled atmosphere caught the attention of the Indian nuclear scientists. They adapated a 'vibriosol' process in which the mixed oxide fuel is prepared through a wet chemical route starting with the calcination of gels in uranyls and plutonium nitrate solutions to get mixed oxide microspheres of different-sized-fractions and packing them into fuel by vibratory compactions to achieve 90% smear density.

In the internal gelation process for preparing mixed oxide microspheres, the nitrate solution of the actinides are mixed and cooled and to this solution, concentrated hexamethylene tetramine and urea solutions which act as internal gelation agents are added. Droplets of this solution are gelled by contact with hot silicon or paraffin oil. This method, preferred to the cold processing sintering process, involves less fabrication steps, maximum flexibility of operation, high degree of microhomogeneity of microspheres, low radioactive dust dispersion on glove boxes and other equipments and is suitable for automation and remote operations. Safety consideration demand, however much engineering and process control against expulsion of fuel pellets to the coolant circuit which may be less in pellet circuit. The fabrication of fuel for the fast breeder reactor at Kalpakkam from uranium resources and plutonium (thus replacing the need for enriched uranium (235) and the fabrication of the MOX fuel for TAPS, the fabrication of the zircalloy-clad 2-4% enriched uranium dioxide for BWR with 2-5% PuO was achieved at BARC. Fabrication of fuel is a tricky problem (with uniform distribution of plutonium in the MOX fuels).

A train of interconnected glove boxes for the preparation of MOX granules starting from UO and Pu powders by milling, blending pre-compaction, granulation, etc., a compaction-sintering train with a 30-tonne automatic double action hydraulic press, dewaxing furnaces and a continuous sintering furnace were fabricated indigenously. A centreless grinder for grinding pellet to final diameter, a welding train for vacuum degassing of sintered pellets followed by loading of pellets in a one-end welded pre-autoclaved 4″ long zircalloy-2 tubes and encapsulation by TIG welding under helium pressure of around 0.3 MPa was also designed and fabricated at BARC. Further a train of gloveboxes for refabrication of the sintered MOX pellets from rejected oxide and facilities for non-destructive testing of zircalloy hardwared and fuelpins by airganging, ultrasonic testing, radiography, X-ray diffraction and X-ray fluoroscene spectrometry was also achieved. Besides the preparation of all the free flow diagrams of all processes involved was also obtained through systematic studies, experimentation and pilot plant studies and testing. All these facilities were fabricated at BARC in a relatively short period and indigenously by interdisciplinary mission-oriented research programmes.

Irradiation testing of a prototype MOX fuel cluster of pins and a second cluster for TAPS were undertaken at BARC by simulating the operation conditions. Mixed carbide and nitride fuel for use in the light-mixed fuel breeder reactors by synthesis of (UpU) C and (UpU) N by carbothermic reduction of mechanically mixed uranium and plutonium dioxide and graphite powders were compacted in the form of tablets in vacuum or flowing argon for the carbide and flowing nitrogen +8% hydrogen mixture (for the nitride), then they were later crushed, coldpressed and sintered in argon, argon +8% hydrogen of vacuum.

In atomic energy research and especially in plutonium metallurgy, India has travelled many milestones, met many challenges, probed many new frontiers indigenising all aspects of plutonium metallurgy and their commercial exploitation in nuclear power reactors. The country is now in a position to utilize 100 to 150 tonnes of fissile plutonium obtained as a by-product from reactors with depleted uranium and recycle them several times with depleted uranium in LMFBR, prepare for a 238, 239 fuel cycle and simultaneous conversion of thorium (232) to uranium (233) and finally in the third stage, the self-sustaining 232, 233 thermal breeder fuel cycle could be used in PHWR to unlock 1,000 GW(e) for 240 years.

Among other achievements can be mentioned the fabrication of plutonium fuelled prototype FBR reactor design which will be up in the 1990s (capacity 500 MW). A larger capacity plutonium fuel fabrication plant is being built at Tarapur.

Reprocessing

Reprocessing of spent fuel was started with the commissioning of a 30-tonne per annum plant in 1964. Thus 24 years ago, India became the fifth country in the world to start reprocessing. This plant was intended primarily for reprocessing the fuel from the CIRUS research reactor and was built in four years by Indian engineers and technicians based on Indian technology. The cost of this plant was less than half the estimated cost of a similar capacity plant under construction at that time in another country.

The Trombay plant adopted the purex process using mechanically pulsed solvent extraction columns with 30% TBP as solvent. The separated plutonium is purified by anion exchange and the residual uranium by further solvent extraction. The Trombay plant has helped in generating expertise and training manpower in the design, construction and operation of future reprocessing plants in the country. The Trombay plant was shut down partially decommissioned and decontaminated for incorporating additions and alterations for expansion of its capacity and extension of its life.

Based on the experience gained at Trombay, a 100 tonnes per year Power Reactor Fuel Reprocessing Plant (PREFRE) has been set up at Tarapur for reprocessing zircalloy-clad uranium oxide fuel elements from the Tarapur Atomic Power Station. The Tarapur plant uses the chop leach method at the head and followed by dissolution, solvent extraction, separation of fission products, purification of separated plutonium and residual uranium and conversion to oxide forms. The plant has a fuel storage pond together with its water purification system and associated mechanical handling equipment. This plant will also have a separate stream for reprocessing fuel from the Fast Breeder Test Reactor.

The optimum size of a reprocessing plant is a function of parameters specific to a country in which it is located. Under the conditions prevailing in India presently, 100-200-tonne capacity plants have been determined to be the most optimal. India's experience clearly indicates that it is possible to construct such capacity plants economically with costs, both initial as well as operating, much lower than reported reprocessing costs elsewhere in the world. Some of the important factors which contribute to comparatively lower costs in India even for smaller plant could be (1) an order of magnitude difference in skilled labour costs resulting in lower capital and operation costs (2) lower construction cost and (3) lower engineering and commissioning cost. Thus, in the immediate future, India will continue with reprocessing plants in the range of 100-200 tonnes capacity.

Radioisotopes

The benefits of nuclear science are being dessiminated as the country has developed expertise to manufacture radioisotopes for use in wide ranging fields like medicine, industry, agriculture, hydrology and scientific research.

At present about 400 radioactive isotopes and labelled compounds are being produced by BARC. Among the methods of artificial isotopes production, bombardment of stable element with neutrons in a nuclear reactor is the most important one and is being followed by the large-scale production of isotopes in the country. Radioisotopes so produced are purified and later converted into suitable physical or chemical forms for different uses.

During production of isotopes, samples are irradiated in specially designed tray rods. A tray rod can hold 72 capsules of 2.2 cm diameter and 7.5 cm length containing samples for irradiation. The tray rods are installed in fuel channels as required, and are cooled by heavy water. The one power fuelling machine is used for loading and unloading of the tray rods. The tray rods permit enhanced production of a variety of radioisotopes such as iodine-131, chromium-51, and molybdenum-99. Besides, Indian reactors are also producing iodine-125, an important radioisotopes used in radioimmunoassay and iridium-192, required for the fabrication of intense gamma ray sources used in compact radiography cameras.

Over 1,600 samples of various target materials were irradiated in the CIRUS and APSARA reactors. These include a set of 12 antimony pins irradiated in CIRUS for producing 150 curies of antimony-124 for use in start up neutron sources for Fast Breeder Test Reactor at Kalpakkam. Besides, DHRUVA reactor is also producing small quantity of molybdenum-99, and other isotopes. A total of 50,000 consignments of radioisotopes and related equipment valued at Rs. 2.3 crore were supplied to the users in the country and abroad during 1985-86. Major supplies included nine cobalt teletherapy sources supplied to various cancer hospitals, four for research and 135 kilocuries of cobalt-60 sources installed at the radiation sterilization of medical products plant at Trombay.

BARC is producing radioisotopes such as sodium iodide (iodine 131), sodium chromate (Cr. 51) rose bengal (I-131) hippuran (I-131) vitamin B 12 and cobalt 57 which are being extensively used in routine diagnosis of thyroid disorders and investigations of blood volume and anemia. Sodium iodine (I-131) is also being used in the therapy of some thyroid disorders including cancer and also the sodium phosphate (P-32) in the treatment of blood cancers. Besides, BARC is producing Technetium-99m generators which contains its longer lived parent, molybdenum-99 isotope which can be incorporated in a variety of pharmaceutical forms suitable for early detection of cysts, abscesses and cancer in brain, heart, liver and thyroid.

A good range of radioimmunoassay, a versatile and simple radioisotopic procedure for the quantitative estimation of minute amounts of many important biological substance in body fluids like hormones, antigens, drugs and infection agents, reagents and kits to detect thyroid disorders, problem of pregnancy and other diagnostic application, have also been developed by BARC.

Use of radioisotopes helps to study the functioning of different parts and organ systems of the body, such as the liver, the kidneys and the spleen, thus enabling the detection of different disease states. Scanning of essential organs, such as the thyroid, the liver and the kidneys, using radioisotopes is being performed in various hospitals of the country. By studying scans of tumours their treatment by surgery or radiotherapy can be more easily planned. In the field of radiotherapy, radioactive iodine is being used in the therapy of hyperthyroidism and thyroid cancer.

BARC has also developed methods for the fabrication of a variety of radiation sources for cancer therapy. Radiation therapy which uses gamma rays from radioisotopes is an effective method of treating various types of cancer. Cobalt-60, iridium-192, caesium-137 and gold 198 are some of the commonly used radioisotopes produced by BARC for this purposes. Besides, BARC has developed methods for the fabrication of a variety of sources used in both teletherapy and brachytherapy techniques. In teletherapy a collimated beam from an intense gamma source house in a lead shield is directed towards the tumour region. Fabrication of teletherapy sources involves remote encapsulation of multikillocurie quantities of radioisotopes such as cobalt-60 in facilities known as hot cells. Application of discrete source in body cavities is known as brachytherapy. This method is being used for the treatment of carcinoma of cervix and cancer of the breast. BARC has set up a large radiopharmaceuticals laboratory named ISOPHARM, at Vashi in New Bombay, for the regular production of a wide range of radiopharmaceuticals and radioimmunoassay reagents and kits. BARC is also setting up the regional centres for radiopharmaceuticals and radioimmunoassays. The first one, located at Kidwai Memorial Institute of Oncology, Bangalore, has been commissioned and is providing extensive services to nuclear medicine users in and around Bangalore. The centres at Delhi and Dibrugarh are likely to be commissioned soon. DAE has also set up a labelled Biomolecular Laboratory at Hyderabad. This laboratory will provide vital tools of research in biotechnology.

BARC has developed a wide range of radiography equipment to meet the country's demand not only for radiation sources and equipment, but also for manpower and expertise in the field of modern, non-destructive testing of industrial components and structures. Iridium-192 and cobalt-60 exposure devices (cameras) are being used. Nucleonic gauges are being used for control of level in closed containers, measures thicknesses of pipes, foils, sheet metal and many such process-control applications.

The isotopes are being used to locate minute leaks in pipelines such as the 140-km-long underground pipeline that runs from Viramgam to Koyali in Gujarat. The use of radioisotopes in this field has significantly reduced the time and effort in many industrial activities. Expertise developed by BARC is available for studying seepage at dams using radioisotopes as traces and work has already been done at many sites. Movement of silt is studied with the help of radiotracers at BARC which is vital for dredging operation in some of the harbours. Radiation treatment of sewage sludges in order to kill all living organisms in it has many proven advantages. A plant for hygenisation of sewage sludge is being set up at Baroda. A cobalt-60 irradiator of the plant will treat up to 110-cubic metre per day of sewage sludge emnating from 20 million litres of sewage. The plant will generate data for a full-scale application of this technology.

For inspection of 10-200 mm of steel or equivalent, about 850 cameras are in use in over 500 industrial establishments in India.

BARC studies have convincingly demonstrated that radioisotopes can be used to produce improved mutant of several crop plants. A programme for the development and production of phosphorus-32 labelled biomolecules has been undertaken by BARC to aid research in genetic engineering, enzyme technology and energy related areas. It has also conducted extensive research programme in many areas of food preservation and has developed the basic data to design food irradiators for future requirements.

BARC has set up facility for sterilization of medial products like sutures, blood donor and transfusion sets, infusion assemblies, surgical blades and dressings and some pharmaceutials. Over 120 million items are being sterilized annually by radiations.

Isotopes are also being used to study ground-water recharge, seater intrusion into coastal aquifers, seepages in dams and canal systems. Besides, they are also being used to study sediment movement on sea bed in a large number of ports and harbours. The isotopes are also being used as tracers for diagnosis of problems in industrial processes ranging from leak detection in buried pipelines to assessment of functioning of chemical reactors. Almost all steel plants use radioisotopes to monitor wear of refrectory lining of blast furnaces. Radioactive mercury is routinely used for mercury inventory in caustic soda plants.

Bedload movement in the Hooghly estuary has recently been studied using a particular glass tracer labelled with radioactive scandium-46. The tracer was deposited on the estuary bed and its movement was followed by under-water nuclear detectors. The study helped in assessing the rate of movement of dregged silt from the dumping site. Over 35 such studies have been carried out by BARC in Indian ports and harbours over the last four decades resulting in, certain cases, savings to the tune of crores of rupees in dredging costs.

Waste Management

The importance of radioactive management was recognized very early in India and R&D work at Trombay was initiated much ahead of the power programme. This lead time and technological preparedness resulted in effective management schemes for wastes from the subsequent operations of research and power reactors and fuel reprocessing plants. Based largely on indigenous materials and capabilities, the waste management programme in India is well established and complies with the stringent stipulations that prevail in respect of discharge of radioactivity to the environment.

In India the basic philosophy for management of radioactive wastes has been to concentrate and contain as much radioactivity as possible and discharge to the environment only effluent at "as low a concentration level as practicable." Backed up by 40 years of experience in R&D and operation of facilities at Trombay for treatment and disposal of radioactive wastes, different waste management schemes for the different types of plants in the nuclear fuel cycle, from mining to reprocessing have been designed and installed and are being operated. The schemes have depended on whether the plant location is inland or coastal. For low level liquid wastes at inland site such as Rajasthan or Narora power stations, efforts are to minimise, if not totally prevent, discharge into the environment whereas at coastal sites such as Tarapur or Madras power stations, significant dilution in the sea is possible. For low level solid wastes, no direct disposal into the ground is practised. Different types of containments are used and located at site selected on the basis of geological and geohydrological evaluation. Even then, rigorous monitoring of ground water and soil is continuously carried out. This is followed up by more elaborate environmental surveillance through special laboratories set up near nuclear installations.

More than 99% of the total radioactivity in the entire nuclear fuel cycle is generated from the fuel reprocessing plant. To ensure that this highly radioactive waste stream does not pose any hazards to the environment, a three-stage approach has been adopted.

First, the waste will be incorporated in stable and inert solid matrices. The conditioned waste will then be placed in canisters and kept in a retrievable store under cooling and constant surveillance. Ultimately, the canisters will be stored in suitable geological media.

A Waste Immobilization Plant for incorporating the high level radioactive wastes generated from the fuel reprocessing plant is set up along with the solid storage surveillance facility at Tarapur. Immobilization involves verification of radioactive waste which is coded at underground disposal. The canisters in storage will be air-cooled by natural convection and when the heat and radioactivity in canister decay to the desired level, they will be transported to a suitable geological formation for ultimate storage. The work on identifying suitable geological formations for ultimate disposal has been completed and a graveyard for storage of nuclear waste has been established in Trombay.

CONTRIBUTION OF INDIAN INDUSTRY TO THE NUCLEAR POWER PROGRAMME

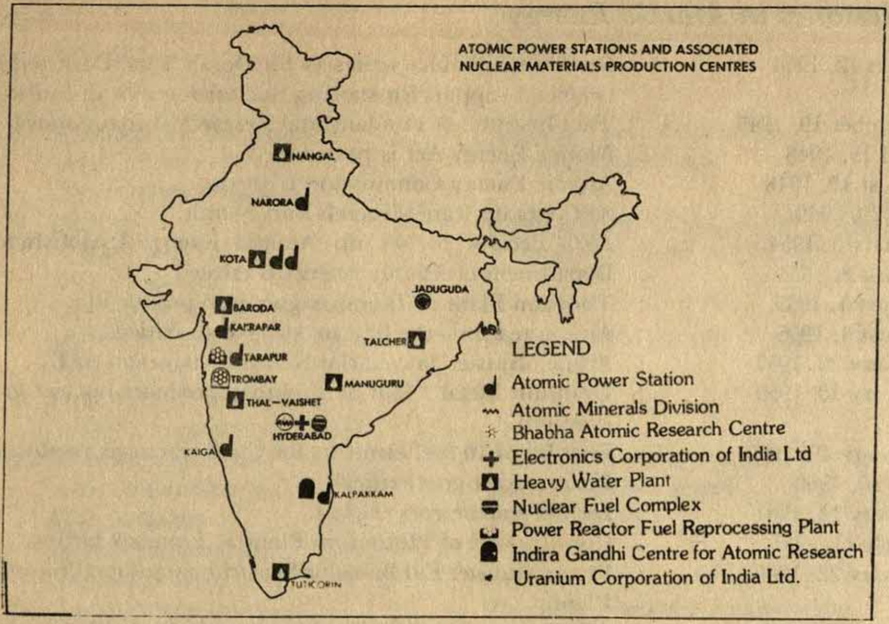
Industry	Supply
1. Alkali Metal Limited, Hyderabad	Sodium
2. Bharat Heavy Electricals Limited, Bhopal	Turbogenerator and feed water plant.
3. Bharat Heavy Electricals, Hyderabad	Reactor Vessel. Thermal Shields. Large and Small Rotating Plugs. Liquid Metal Seals. Vessel and Plug Support.
4. Bharat Heavy Electricals Limited, Trichi	Steam Generators. Intermediate Heat Exchangers. Stainless Steel Piping (Primary). Carbon and Alloy Steel Valves.
5. Development Consultants Pvt. Ltd., Calcutta	Design Consultancy for Civil & Electrical Works.
6. Electronics Corporation of India Limited, Hyderabad	Consultancy service for control & instrumentation. Control & Instrumentation packages. Central Data Processing system. Site installation of control & instrumentation.
7. Engineering Construction Corpn., Madras	Civil Construction Work.
8. Everest Engineering Works, Coimbatore	Mixers and pull-outs. Decontamination vessels. Material airlock bellows.
9. Heavy Engineering Corpn., Ranchi	Special Steel Forgings for Block Pile.

Industry	Supply
10. Keltron, Trivandrum	220 Volt Uninterrupted Power Supply.
11. Kirloskar Brothers Limited, Kirloskarwadi	Charging and Discharging flasks. Flask for control rod drive mechanisms and level detectors.
12. Machine Tools Aids and Reconditioning, Hyderabad	Machined parts of core sub-assemblies. Canal valve assemblies, couplings & sealing ring.
13. Mukund Iron & Steel Works, Bombay	Piping works at site.
14. New Standard Engineering Co. Ltd., Bombay	60 Te Polar crane for Reactor Containment Building.
15. NGEF Limited, Bangalore	High and Medium Voltage switchgears, High and Medium Voltage Motors, Medium Voltage MCCs.
16. Transformers & Switch Gears Limited, Madras	10 MVA Main Transformers.
17. Triveni Structural Limited, Naini	Overflow Tank. Secondary Sodium Storage Tanks. Cyclone Separator. Cold Traps. Secondary Flask. Carriage for Special Flask. Decay Pits. CI Blocks for Discharge Pits.
18. Variety Engineers Pvt. Ltd., Baroda	Shielding Blocks. Transfer Carriage No. 1 & 2 Capsule Transfer Gripper. Steel Sheilding Doors. Transfer Chamber Plug Storage Pits. Decontamination Vessel. Special Flask No. 3.
19. Walchandnagar Industries Limited Machine Tool Division, Pune	Control Rod Drive Mechanisms. Core Cover Plate Mechanisms. Plug Drive Mechanisms.
20. Walchandnagar Industries Limited, Walchandnagar	Control Plug. Anti-explosion floor. Fuel Handling Canal Sodium Pumps.
21. Bharat Heavy Electricals Ltd. Larsen & Turbo Ltd. Walchand Industries Ltd. Industrial & Agricultural Bharat Heavy Plates & Vessels Ltd. Cooper Engineering Ltd.	Heavy equipment. Calandria, end-shields, fuel handling equipment steam generators, turbogenerators and heat exchangers.

Industry	Supply
22. Braithwaite & Co. Ltd. Kaveri Structurals Ltd. Triveni Structurals Ltd.	Structural steel fabrication for reactor buildings.
23. Midhani Bharat Forge Ltd. W.G. Forge Ltd. Visweswaraiah Iron & Steel Ltd.	Forging requirement for end fittings, bearing sleeves and journal rings.
24. Central Foundary and Forging (BHEL) Metal Forging Pvt. Ltd. Golden Iron and Steel Works	Forgings for tube sheet nozzles.
25. Instrumentation Ltd. Audco Industries Ltd. Akay Industries Fouress Engineering (India) Pvt. Ltd.	Valves (other than those for primary coolant system).
26. Cooper Engineering Ltd. Kirloskar Brothers Ltd. Machine Tools Aids and Reconditioning	Precision machined components.
27. Jyoti Ltd. Bharat Pumps & Compressors Ltd.	Heavy water pumps for moderator circuits.
28. K.S.B. Pumps Ltd.	Primary coolant pumps.
29. G.R. Engineering	Distillation columns and electrolytic cells for heavy water upgrading plant.
30. Bharat Heavy Electricals Ltd. New Government Electric Factory English Electric Co. Ltd. Kirloskar Electrical Ltd. Larsen & Toubro Ltd. Siemens India Ltd. Hindustan Brown Bovery Ltd. Universal Cables Ltd. Indian Cable Co. Ltd. Cable Corporation of India Ltd.	Electrical equipment and cables.
31. Electronics Corporation of India Ltd. Instrumentation Ltd.	Process and control instrumentation for nuclear power plants.

Milestones in Atomic Energy

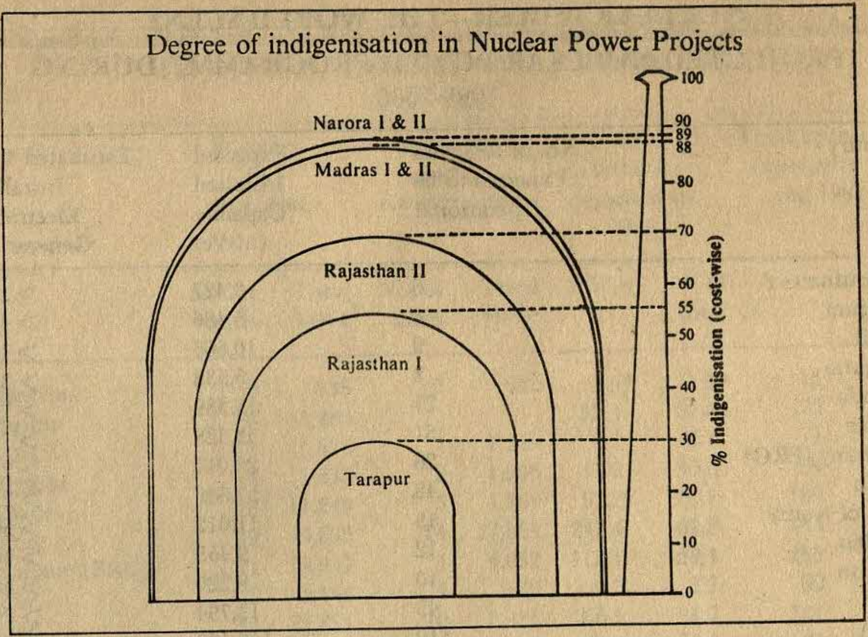
March 12, 1944 : Dr. Homi Bhabha writes to Sir Dorab Tata Trust seeking financial support for starting nuclear research in India.
December 19, 1945 : Tata Institute of Fundamental Research is inaugurated.
April 15, 1948 : Atomic Energy Act is passed.
August 10, 1948 : Atomic Energy Commission is set up.
July 29, 1949 : AEC sets up Rare Minerals Survey unit.
January 3, 1954 : AEC decides to set up Atomic Energy Establishment.
August 3, 1954 : Department of Atomic Energy is created.
August 1, 1955 : Thorium Plant at Trombay goes into production.
August 4, 1956 : Apsara reactor—the first in Asia—goes critical.
January 20, 1957 : Prime Minister Jawaharlal Nehru inaugurates AEET.
January 30, 1959 : Uranium Metal Plant at Trombay produces nuclear grade uranium.
February 19, 1960 : First lot of 10 fuel elements for Cirus reactor is produced.
July 10, 1960 : Cirus reactor goes critical.
January 14, 1961 : Zerlina reactor goes critical.
March 27, 1961 : Construction of Plutonium Plant at Trombay begins.
January 22, 1965 : Prime Minister Lal Bahadur Shastri inaugurates Plutonium Plant.
January 12, 1967 : AEET is renamed as Bhabha Atomic Research Centre by Prime Minister Indira Gandhi.
February 1969 : TAPS I & II achieve critically.
September 6, 1970 : Uranium-233 is recovered from irradiated thorium.
February 18, 1971 : Plutonium fuel for Purnima is made at Trombay.
August 1971 : RAPS-I achieves criticality.
May 18, 1972 : Purnima-I goes critical.
May 18, 1974 : Peaceful nuclear explosion experiment at Pokhran.
November 18, 1979 : Plutonium-uranium mixed oxide fuel is fabricated.
October 1980 : RAPS-II achieve criticality.
November 19, 1982 : Power Reactor Fuel Reprocessing Plant at Tarapur reprocesses uranium oxide fuel.
January 27, 1984 : MAPS-I declared commercial.
March 8, 1984 : Plutonium-uranium mixed carbide fuel for FBTR is fabricated at Trombay.
May 10, 1984 : Purnima-II, a U-233 fuelled reactor, goes critical.
October, 1984 : Nuclear Power Board established.
March 4, 1985 : Waste Immobilisation Plant at Tarapur is commissioned.
August 8, 1985 : Dhruva reactor goes critical.
October 18, 1985 : Fast breeder test reactor goes critical.
December 16, 1985 : RRC renamed as the Indira Gandhi Centre for Atomic Research and FBTR dedicated to the nation by the Prime Minister Rajiv Gandhi.
March 21, 1986 : MAPS-II declared commercial.
October 28, 1986 : Heavy Water Plant at Thal (Maharashtra) starts trail production.
November 26. 1986 : Labelled Biomolecules Laboratory at Hyderabad inaugurated by Prime Minister Rajiv Gandhi.
September 17, 1987 : Nuclear Power Corporation of India Ltd., starts functioning.


ATOMIC POWER STATIONS AND ASSOCIATED
NUCLEAR MATERIALS PRODUCTION CENTRES
NANGAL
NARORA
KOTA
JADUGUDA
BARODA
KAKRAPAR
TALCHER
TARAPUR
TROMBAY
MANUGURU
THAL-VAISHET
HYDERABAD
KAIGA
KALPAKKAM
TUTICORIN
LEGEND
Atomic Power Station
Atomic Minerals Division
Bhabha Atomic Research Centre
Electronics Corporation of India Ltd
Heavy Water Plant
Nuclear Fuel Complex
Power Reactor Fuel Reprocessing Plant
Indira Gandhi Centre for Atomic Research
Uranium Corporation of India Ltd.

COMPARISON OF RISK FROM RADIATION WITH RISKS DUE TO OTHER ACTIVITIES

Cause	Chances of death/year
Smoking 20 cigarettes/day	1 in 200
Accidents in deep sea fishing	1 in 400
Natural causes, 40 year old	1 in 500
Accidents on the road	1 in 5,000
Accidents in the home	1 in 10,000
Accidents at work	1 in 20,000
Radiation work at nuclear facilities (500 millirems per year)	1 in 20,000

SOURCE: "LIVING WITH RADIATION," a document published by the National Radiological Protection Board, U.K.



COST OF NUCLEAR & THERMAL STATIONS THAT WOULD BE COMMISSIONED AROUND 1992 (BOTH ASSUMED TO OPERATE AT 75% CAPACITY FACTOR)

	2×235 MWe nuclear units located anywhere in India	2×210 MWe thermal units located at pit head of coal mines
Capital Cost	Rs. 724 crores	Rs. 621 crores
Capital Cost per Installed KW	Rs. 15,404/-	Rs. 14,786/-
Cost per unit for fuel	10.85 P	39.27 P
Heavy Water Lease & make-up	14.55 P	—
O & M	3.70 P	5.64 P
Depreciation	12.21 P	10.32 P
Return on Capital at 12%	42.36 P	35.87 P
Provision for decommissioning	0.92 P	—
Total Unit Energy Cost	84.59 P	91.10 P*

*If the thermal station is located about 800 kms from the pit head, the total unit energy cost (based on prevailing trends of transportation costs) will be about 109.19 P

Source: Report of the Committee for Pricing of Nuclear Power (Feb. 85).

NUCLEAR POWER—THE WORLD SCENE:

PROJECTED NUCLEAR POWER PROGRAMME DURING 1995-2000

Country	No. of Reactors Expected to be Operational	Expected Installed Capacity (MWe)	Estimated % of Installed Electricity Generation
Argentina	6	3,427	> 20%
Belgium	8	5,486	> 40%
Brazil	9	10,666	> 10%
Bulgaria	8	5,538	> 35%
Canada	21	13,389	> 12%
France	61	53,328	> 75%
Germany (FRG)	26	23,014	> 25%
Japan	48	37,648	> 25%
Rep. of Korea	13	11,012	> 50%
Sweden	12	9,455	> 40%
Taiwan	10	9,220	> 40%
U.K.	43	13,794	> 20%
U.S.A.	119	107,109	>20%
U.S.S.R.	124	101,612	> 20%
India	32	10,090	< 10%
WORLD TOTAL	More than 600	505,000	25:

Data Source: IAEA Power Reactor Information Service. National Policy Statements.

NUCLEAR POWER REACTORS IN OPERATION AND UNDER CONSTRUCTION AT THE END OF 1986

Country	Reactors in operation		Reactors under construction		Nuclear electricity supplied in 1986		Total operating experience to end-1987	
	No. of units	Total MWe	No. of units	Total MWe	TW.h	% of total	Years	Months
Argentina	2	935	1	692	5.4*	11.3*	16	7
Belgium	8	5,486			37.1	67.0	72	1
Brazil	1	626	1	1,245	0.1	0.1	4	9
Bulgaria	4	1,632	2	1,906	11.2	30.0	34	6
Canada	18	11,249	5	4.361	67.2	14.7	169	6
France	49	44,693	14	17,809	241.4	69.8	384	6
Germany (FRG)	21	18,947	4	4,052	112.1	29.4	235	7
India	6	1,154	4	880	4.5	2.7	60	8
Japan	35	25,821	10	8,431	166.5	24.7	321	5
Rep. of Korea	7	5,380	2	1,800	26.6	43.6	21	7
Sweden	12	9,455			67.0	52.3	111	2
Taiwan, China	6	4,918			25.8*	18.8*	32	1
U.K.	38	10,222	4	2,520	51.8	8.4	732	10
U.S.A.	99	84,592	21	23,301	414.0	16.6	1,051	0
U.S.S.R.	50	27,657	32	29,910	148.0*	10.6	579	11
WORLD TOTAL	397	273,715	153	117,848	1514.6		4,210	2

Note Values with an asterisk are IAEA estimates.
Source: IAEA PRIS, Report NBLF030, 87-03-25.

Nuclear Power Reactors are also in operation in China, Cuba, Czechoslovakia, Finland, German Democratic Republic, Hungary, Iran, Italy, Spain, Switzerland and Yugoslavia.

INSTALLED GENERATING CAPACITY

End of each plan period	Public Utilities (in MW)				Total including non-utilities (in MW)
	Thermal	Nuclear	Hydro	Total	
1950	1,152	NIL	559	1,711	2,300
1951-56	1,755	NIL	1,061	2,861	3,418
1956-61	2,736	NIL	1,917	4,653	5,654
1961-66	4,903	NIL	4,124	9,027	10,173
1966-69	7,050	NIL	5,907	12,957	14,297
1969-74	9,058	640	6,925	16,623	18,456
1974-79	15,219	640	10,833	26,692	290,266
1979-80	16,469	640	11,381	28,490	31,307
1980-81	17,563	860	11,791	30,214	33,316
1981-82	19,312	860	12,173	32,345	35,781
1982-83	21,447	860	13,056	35,363	39,235
1983-84	24,389	1,095	13,855	39,339	43,754
1984-85	26,880	1,095	14,470	42,445	47,269
1985-86	29,861	1,330	15,447	46,638	31,766
1986-87	32,053	1,330	16,681	47,265	N.A.
1987-88 (Target)	N.A.	N.A.	N A	53,318	N.A.

Source: Public Electricity Supply Statistics—All India, Ministry of Energy Annual Report.

PERFORMANCE OF NUCLEAR POWER PLANTS

	TAPS UNIT-1			TAPS UNIT-2			RAPS UNIT-1			RAPS UNIT-2			MAPS UNIT-1			MAPS UNIT-2		
Year	Availability factor (%)	Capacity factor (%)	Total No. of outages	Availability factor (%)	Capacity factor (%)	Total No. of outages	Availability factor (%)	Capacity factor (%)	Total No. of outages	Availability factor (%)	Capacity factor (%)	Total No. of outages	Availability factor (%)	Capacity factor (%)	Total No. of outages	Availability factor (%)	Capacity factor (%)	Total No. of outages
1969	93	54	6	86	50	5	—	—	—	—	—	—	—	—	—	—	—	—
1970	85	59	13	79	60	23	—	—	—	—	—	—	—	—	—	—	—	—
1971	59	46	6	68	51	6	—	—	—	—	—	—	—	—	—	—	—	—
1972	57	35	15	23	12	2	—	—	—	—	—	—	—	—	—	—	—	—
1973	59	41	15	85	68	14	89	49	2	—	—	—	—	—	—	—	—	—
1974	79	45	21	46	32	19	54	38	49	—	—	—	—	—	—	—	—	—
1975	66	50	3	65	50	8	44	34	31	—	—	—	—	—	—	—	—	—
1976	87	63	12	74	62	6	65	47	35	—	—	—	—	—	—	—	—	—
1977	70	54	15	85	68	7	38	27	11	—	—	—	—	—	—	—	—	—
1978	73	51	11	76	62	11	18	9	9	—	—	—	—	—	—	—	—	—
1979	82	53	6	71	54	6	82	65	14	—	—	—	—	—	—	—	—	—
1980	68	48	5	78	49	13	72	54	19	—	—	—	—	—	—	—	—	—
1981	68	43	12	77	52	9	43	26	13	80	44	21	—	—	—	—	—	—
1982	90	60	14	55	30	10	6	3	4	42	23	9	—	—	—	—	—	—
1983	62	43	6	86	57	6	—	—	—	75	55	15	—	—	—	—	—	—
1984	88	49	6	64	47	4	—	—	—	61	54	16	75	64	24	—	—	—
1985	71	58	7	92	78	5	22	13	6	71	59	15	55	46	13	—	—	—
1986	91	85	10	64	59	5	—	—	—	11	70	11	53	41	13	57	41	23
1987 (till July)	5	4	1	97	94	1	1	—	—	92	85	4	85	71	13	75	59	18

Biotechnology

WITH ITS strong background in the traditional areas of plant, animal and medical sciences, India is now poised to become the first developing country in this part of the world to make use of biotechnology to solve many problems being faced in medicine, agriculture and industry after breaking big powers' monopoly in nuclear energy, space and deep sea mining.

In recent years, biotechnology, which involves use of novel microbes altered or manipulated by man through genetic engineering techniques, has emerged as an important discipline. It can be broadly defined as the development forms and systems for obtaining maximum benefits to man and other forms of life while maintaining an optimum ecological balance by the use of conventional and non-conventional techniques of interaction between the living and the non-living as well as between the living and the living.

Over the years, man has exploited biological processes in various technologies such as fermentation of alcoholic beverages, food processing and preservation, retting of fibres, curing of tobacco, production of vaccines, pharmaceuticals and other chemicals and recycling of industrial and animal wastes. The recent epoch-making discoveries which have led to the development of techniques of genetic engineering, cell-cell fusion amongst plants and animals and microorganisms and manipulation of enzyme and metabolic pathways have opened up new possibilities for the cost-effective production of fuel from renewable resources, cloning and better yielding varieties of plants, low cost medical testing kits, better methods for early diagnosis of selective methods of pest control and purification of waste water. Several basic disciplines of science like biochemistry, physics, mathematics, chemistry and engineering have an inter-face with biotechnology.

The profoundness of biotechnology is its ability to manipulate the core of all living matter namely DNA itself. The addition of new genes into plants animals and microorganisms provides vast opportunities for its application to resolve diverse but highly relevant to national problems that are presently prevalent in the country. The new technologies that are being evolved offer to us an extremely efficient and cost effective solution to these problems. Biotechnology offers through the use of high technology solutions which otherwise may not be possible within a meaningful time-frame and our present resource constraints.

In many ways, India, which is geographically located in the tropical and sub-tropical region, is abundantly endowed with natural resources and nature's kindness in terms of abundant sunshine, adequate rainfall, moderate temperature conditions for year round, plant growth and an extremely fertile top soil especially in her vast river basins. The exploitation of the newly developed tools in biotechnology, therefore, becomes appropriate to such conditions. At the same time, these techniques and technologies which have been developed primarily in the Western countries need to be properly absorbed and adopted and turned into inventive new approaches for solving our problems.

The grounding and advances in basic research in Indian universities and institutes over several decades have made possible the emergence of biotechnology as an inter-disciplinary thrust area of research with a potential future.

Genetic Engineering

Work on genetic engineering has been taken up at a number of institutions in the country. In New Delhi various institutions are active in this field. Studies are being carried out on transfer of nitrogen fixing genes into the chromosomes of cereal bearing plant through recombinant DNA technology at the School of Environmental Sciences, Jawaharlal Nehru University. Construction of M-Leprae DNA library and cloning of DNA and coding hormones, human chorionic gonadotropin (HCG) and human placental lectogen is in progress at the National Institute of Immunology (NII). Scientists at the NII have successfully tried anti-fertility vaccine in monkeys and human trials will be completed soon.

At the Indian Agricultural Research Institute, an active group is working on characterization of translation and transcription processes in *Escherichia coli* during cell division and gene expression in plant tissues. At Indian Institute of Technology, Delhi, stress is given on conversion of cellulose to alcohol and this is the major facility in the country for detailed studies in all aspects of fermentation. At the CSIR Centre for Biochemicals, support facility has been created to ensure that restriction enzymes and other strategically important materials are readily available. The institute had already started manufacture of few enzymes saving considerable foreign exchange.

Two of the major institutions in Bombay active in the field of genetic engineering are Tata Institute of Fundamental Research and Bhabha Atomic Research Centre where work is going on cloning of genes of *Agrobacterium* and *Drosophila.* The technique is being used in the area of transfer of nitrogen fixing (nif) genes to other microorganism and plant cell. Efforts are also being made to develop and make available techniques and suitable microbe that bring about biological nitrogen fixation in irrigated and wet land cultivation condition such as *Rhizobia,* blue green algae. The Department of Zoology at Poona University is working on cloning of mosquito resistance genes. The Department of Zoology, Delhi University, and Malaria Research Centre, Delhi, are studying cell biology ultrastructure and electron cyto-chemistry of the human malaria parasites *Plasmodium vivax* and *P. falciparum.* The Department of Biochemistry at the National Chemical Laboratory is also making significant contributions in this area.

Several groups are active in the Indian Institute of Sciences, Bangalore, working in diverse areas like gene expression in rinderpest virus. Histone gene expression in rice embryos, structure and expression of genes regulating silk, fiboin synthesis in *Bombax mori,* regulation of nitrogen fixation, etc. Work on molecular cloning and sequencing of genes, coding for restriction and anti-restriction proteins in *E. Coli* and *Shiegella dysenteriae* as well as cloning of biocide gene from *Bacillus spharicus* and *B. thuringiensis* is being pursued at Madurai Kamaraj University, Madurai, Osmania University and Centre for Cellular and Molecular Biology house two active groups at Hyderabad. Indian Institute of Chemical Biology and Bose Institute and Saha Institute of Nuclear Physics are leading institutions in Calcutta where several groups are working on application of genetic engineering techniques, studies of biological nitrogen fixation and insertion of genes of applied importance to bacteria.

At Varanasi (Uttar Pradesh) work on cloning of genes of the bacteriophase MB No. 78 RNAse 1 in *E. Coli* are being done at the Institute of Medical Sciences, other centres of activity include All India Institute of Medical Sciences, New Delhi, Central Drug Research Institute, Lucknow. and Aligarh Muslim University, Aligarh.

Realising the hazard involved in genetic engineering National Biotechnology Board (NBTB), and now Department of Biotechnology, has formulated safety regulations in the field of recombinant DNA technology. A special committee set up by the board has formulated guidelines relevant to the Indian conditions on the basis of the recommendations of the

National Institute of Health, USA. These guidelines are being enforced by the DOB in various institutions and laboratories where the genetic researches are going on.

Fermentation Technology

Biochemical Engineering Research Centre at IIT, Delhi, has several research groups working on different aspects of fermentation technology starting from strain improvement using mutagens, genetic engineering right up to pilot plant fermentations with computer controls. The Department of Microbiology at MS University of Baroda, Indian Institute of Science, Bangalore, National Chemical Laboratory, Pune, Jadavpur University, Calcutta, National Sugar Institute and Harcourt Butler Technology Institute, Kanpur, Regional Research Laboratories at Jammu and Jorhat, Central Food Technology Research Institute at Mysore, Department of Microbiology, Punjab University, Chandigarh, are some of the other important centres where basic studies on fermentation technology are carried on.

Among industries, work on fermentation technology is being actively conducted at Hindustan Antibiotics Ltd., Pimpri, Pune, Anil Starch Products Limited, Ahmedabad, M/s. Bharat Serums and Vaccines, Thane, Cadilla Laboratories Pvt. Ltd. Ahmedabad, Hindustan Lever, Bombay, and at Hoechst Pharmaceuticals, Bombay.

Enzyme Engineering

Major centres in India where work on immobilization of enymes is going on including Hindustan Antibiotics Ltd., Pimpri, Biochemical Engineering Research Centre, IIT, Delhi, National Chemical Laboratory, Pune, Jadavpur University, Calcutta, Indian Institute of Science, Bangalore, IIT, Kanpur and Indian Institute of Chemical Biology. The work being done covers immobilized enzymes for use in medicine, industrial fermentation, food processing and waste water treatment.

Tissue Culture

Tissue culture, the technology of 'artificially' growing cells, tissues and organs to the desired genetic purity and with properties such as high yields and disease-resistance, is poised to go from Indian laboratories to farmers' field.

During last few years, Indian scientists have successfully propagated a large number of plants of papaya, coconut, tobacco, gladiolus, sandalwood and citrus through tissue culture which is considered as an important technique with potential application for improving agriculture crops and plants, forest trees and for the isolation of medicinal compounds for use in pharmaceutical industry.

Over 44 research institutions and universities in the country are working on various applied aspects of tissue culture like clonal multiplication, plant breeding, plant pathology and preservation of plant tissue cultures. The potential of plant cell culture has been vastly improved owing to fast emerging technology of test-tube culture of cells, protoplasts and pollen grains, leading to their regeneration into plants. These techniques not only allow multiplication of selected 'elite' plants in large numbers in a much shorter time but also offer substantial potential for creating and selecting useful genomes.

The University of Delhi is well known throughout the world for its work on endosperm, embryo, ovule, *nucellus* and anther culture. Early emphasis in most laboratories was on basic research. In recent years, however, application of tissue culture to problems of agriculture, horticulture and forestry has received increased attention.

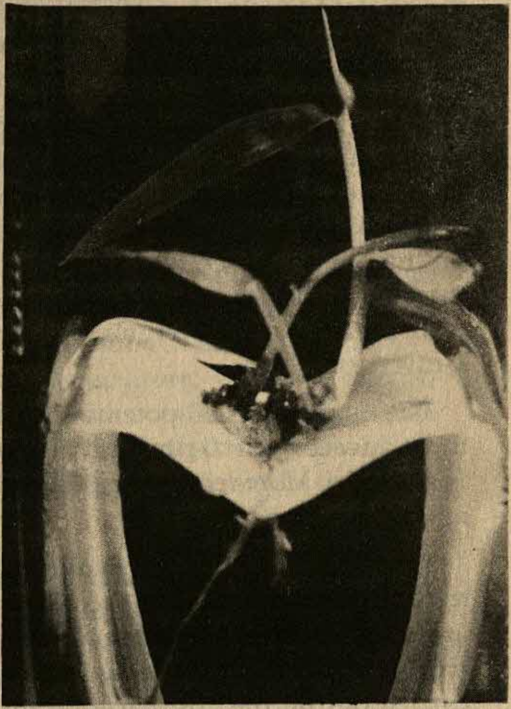
Work on clonal propagation has been undertaken in several laboratories, especially on species of importance to the country. At the National Chemical Laboratory, Pune, methods for multiplication of mature teak and eucalyptus tree have been developed. The propagation of turmeric, ginger, sugarcane, tamarind, cardamom and rose by tissue culture has also been achieved and viable plants have been successfully raised in the field.

At the National Botanical Research Institute the propagation of citrus and of several ornamentals like *Bougainvillea* and of a number of commercially important orchids such as *Cymbidium* and medicinal plants like *Dioscorea deltioidea* and *Rauwolfia serpentina* has been carried out. At the Bhabha Atomic Research Centre methods were developed for the propagation of sandalwood, pineapple, tomato, mustard and at the Indian Institute of Science, multiplication of hybrid tomato, sandalwood and *Eucalyptus citriodora* was studied.

As indicated earlier, pioneering work on embryo culture has been carried out at the University of Delhi but the practical applications of this technique to agriculture have not been fully exploited. Interspecies crosses of cotton, jute and oryza as well as triticale were investigated at the Indian Agricultural Research Institute. *Hordecale* (barley and rye) hybrid embryo has been cultivated at the Punjab Agricultural University.

Work on mutation screening using tissue culture has been undertaken only recently in India. At the National Chemical Laboratory mutants of sugarcane, which appear to be resistant to mosaic virus, turmeric mutants with high curcumin content and spontaneous mutations from wheat callus are being tested for genetic stability and yield. Mutants have been induced in

Test-tube bamboo.



Advanced test-tube bamboo.

Development of test-tube bamboo at Delhi University.

the haploid tissues of *Arabidopsis* and *Streptomycin* resistant clones have been isolated from the haploid callus of datura at the Jawaharlal Nehru University.

Though pioneering work on haploid plants was first carried out in India, this technique is being extensively used only abroad and virtually no work on plant breeding with haploids obtained by tissue culture has been undertaken in the country. However, laboratory work has been carried out on haploids of rice at IARI and datura, tobacco, Atropa, Capsicum, tomato and potato at BARC, on tobacco at the University of Baroda and on rose, potato, cauliflower, mustard and sunflower at the Jawaharlal Nehru University.

The morphological potentiality of endosperm tissue has been studied at the University of Delhi and triploid plants obtained from *Putranjiva roxburghii*. More recently triploid plant have been isolated from Santalum at the IIS and BARC.

The morphological, physiological and biochemical aspects of tumour tissue (induced by viruses, bacteria, fungi and insects) are being investigated at the University of Jodhpur while the Bose Institute is dealing with the basic problems of crown gall tumour in plants. Considerable work has been carried out on the host-bacterial interaction in inducing the gall disease, isolation of bacterial-free tissues and their culture through successive generations, and physiological, nutritional and cytological studies of the two cells types—normal and gall isolated from plants belonging to different families.

Plant cell suspension cultures and production of secondary plant products have received considerable attention at BARC, and at the universities of Jaipur, Jodhpur, Poona and Baroda. Studies on preservation aspect of tissue culture is being carried out at Punjab Agricultural University.

Tissue culture has also been identified as one of the major thrust areas in India by the National Biotechnology Board as well as by the joint Indo-US Commission on Scientific Collaboration. Within a year, institutions like IARI are planning to take their samples to the farmers' fields. How this technology ultimately fares will be its real test.

The National Biotechnology Board (NBTB) and now Department of Biotechnology, which was set up to promote and oversee research in this field, during the third year of its existence, held a number of meetings and completed the working plans for implementing various decisions taken on the major issues namely, integrated short-term training courses for manpower development; formulation of long-term plan with time schedule; finalisation of NBTB Fellowships, visiting scientist programme; formulation of proposals for creation of infrastructural facilities; safety regulations to be followed for DNA research in India, supply of radio-labelled chemicals and restriction enzymes required for genetic engineering and preparation of feasibility report for setting up biotechnology-based manufacturing units.

One of the charters of NBTB is to identify priority areas in biotechnology and prepare programmes in these areas for carrying out research and development work, for generating know-how required for the application of biotechnology in areas of national relevance such as health (human and animal) and family planning, food and agriculture, industry, energy, chemicals, environment, etc., and survey the work done by various agencies in the area of biotechnology. In this connection the long term plan has been formulated in consultation with the sub-committee of Executive Committee of the Board.

The Department of Biotechnology was entrusted to set up and provide centralised assistance for procurement of materials required for genetic engineering from abroad and to initiate follow up action for production of these materials within the country. In view of the urgency, the department initiated a coordinated multi-institutional programme on production of restriction enzymes which are essential for genetic engineering research. Management and monitoring of the project is being done by NBTB. In the first phase of the project production of five enzymes has been completed. As on interim measure, the department arranged for bulk import and distribution of restriction enzymes with the help of CSIR Centre for Biochemicals at VP Chest Institute, Delhi. It is also arranging the centralised import of radio-labelled nucleotides through Bhabha Atomic Research Centre, Bombay.

Simultaneously, effort is being made for the production of radio-labelled nucleotides by BARC. The CSIR has agreed to provide laboratory space and other facilities in the Centre for Cellular and Molecular Biology Campus, Hyderabad.

The department has formulated an integrated plan for conducting short term training courses: Train-Programme in Plant Tissue and Cell Culture; Methods and Applications; Workshop-cum-Seminar on Enzyme-engineering; Training Programme on Recombinant DNA Techniques in Genetic Engineering and Workshop course on 'Gene Cloning & Allied-Techniques under Genetic Engineer Programme. Fellowships are also being given by the department to scientists for shorter, long-term training within this country and abroad. It has been decided to send some scientists abroad in different sectors for training in advanced techniques to expose them to the recent development wherever infrastructural facilities and expertise are not existing within the country.

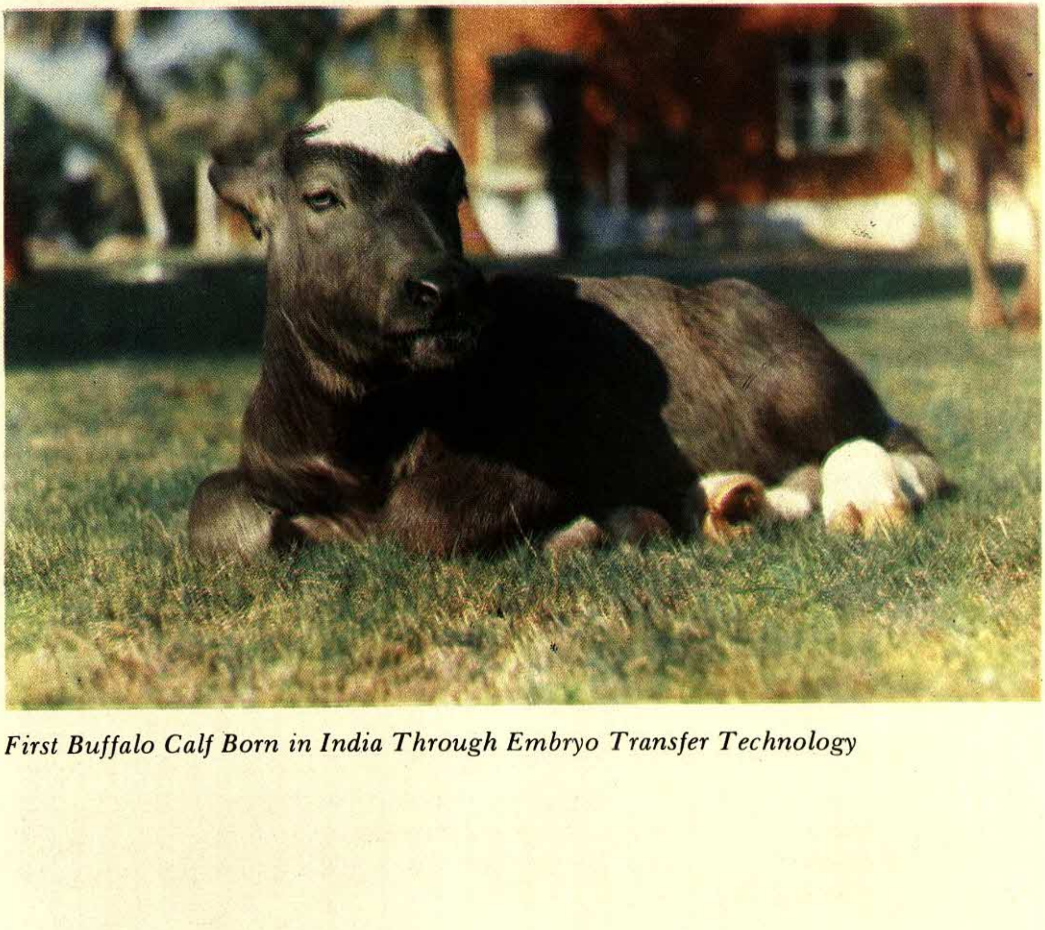
Realising the hazard involved in recombinant DNA research, the department desired to evolve safety regulations. The task was entrusted to a special committee, which on the basis of guidelines followed in other countries viz. National Institute of Health, USA, formulated guidelines relevant to the Indian conditions which were subsequently approved by the department. The guidelines have been printed and circulated widely.

Research and development effort in the field of biotechnology would become crippled for lack of certain essential infrastructural support facilities. The authenticity of microbial culture, animal cell lines, plant cell lines, primate and small animals used in the production of biotechnological product metabolite is an essential pre-requisite for a successful industrial production of the concerned product. Such a rigorous demand can only be met by proper preservation, maintenance, consistency and monitoring of the desirable pool which becomes, therefore, paramount. The need for such centralised facilities having collections of these is thus acute. Nothing that any organised efforts in this direction is yet to take place in our country the following proposals have been formulated by the department in consultation with the experts.

(a) Germplasm banks for microorganisms, protozoa and other parasites, plant and animals tissue and cell lines and viruses; (b) Experimental facilities using non-human primates and specialised small laboratory animals; (c) Pilot plant and other bioengineering scale up facilities for process development and optimisation and for producing sufficient quantities of new products for field trials; (d) Procurement/ manufacture of enzyme, reagents and labelled isotopes essential for R&D work in bioengineering and related fields; and (e) A network of information disseminating system to provide up-to-date S&T information to the scientists working in the frontier area of modern biotechnology.

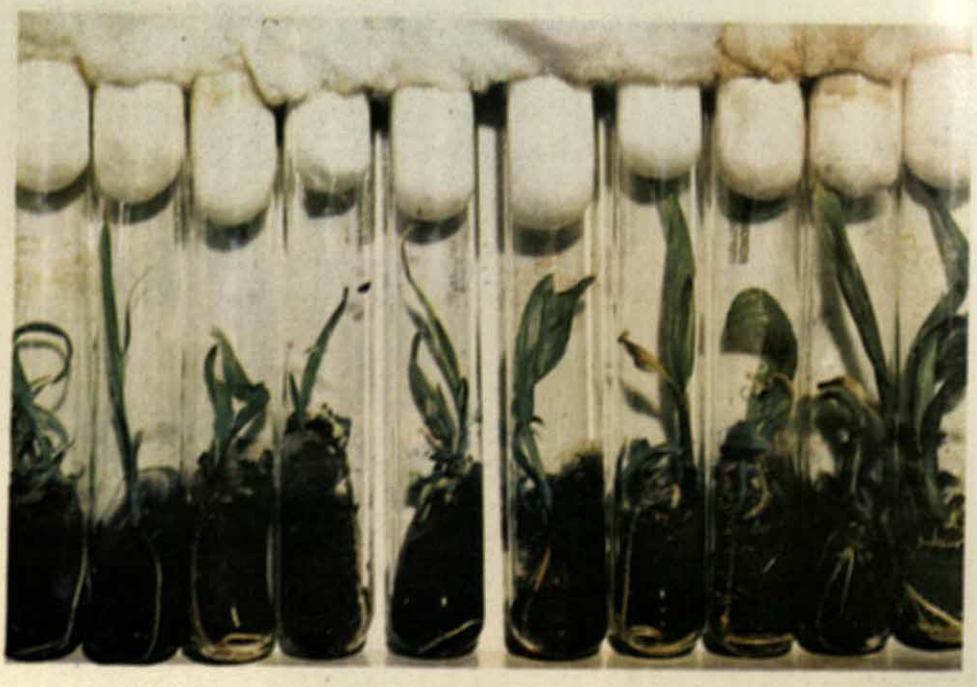
An International Centre for Genetic Engineering and Biotechnology (ICGEB) is being set up at the Jawaharlal Nehru University (JNU), Delhi, with the help of the United Nations Industrial Development Organisation (UNIDO). It will take up research and development work in agriculture, human and animal health, industrial technology for pharmaceuticals and other products.

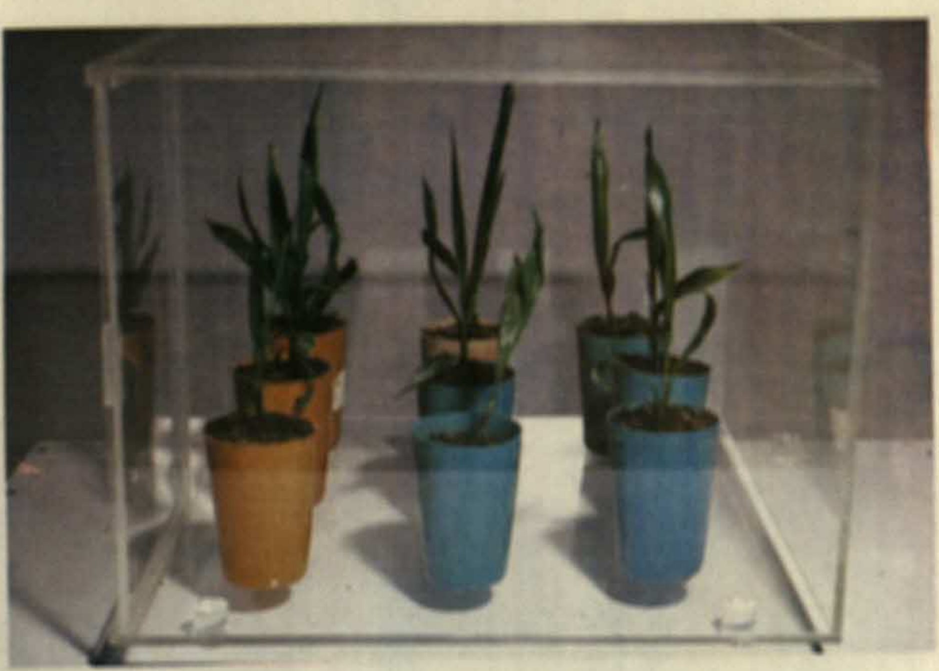
If and when advances in biotechnology are achieved it would benefit not only India but the world as a whole. As a result of the stimulus of the Green Revolution India is aware of potentials for improving crop yields and is maintaining indigenous agricultural stations capable of acting as centres for technology transfer.



First Buffalo Calf Born in India Through Embryo Transfer Technology

Test-tube Oil Palms'





Test-tube Oil Palms in Lab

Test-tube Palms in Field

High-Tech Babies

Test-tube Teak Plant

Health

INDIA'S MAJOR medical research centres are making use of advanced technologies to find solutions to the country's health problems. Scientists are using conventional as well as modern tools of medical sciences like genetic engineering and biotechnology to cope with the present and oncoming health problems like AIDS, tropical diseases and fertility control.

At the forefront of these developments are efforts to develop vaccine against tropical diseases like malaria, leprosy, as also anti-fertility vaccines and high-tech babies. India's first biotechnology product—a pregnancy kit—has already entered the U.S. market. And India's first anti-fertility vaccine is undergoing trials in India and abroad.

Research in medical sciences was started by a few British medical men on their own or as government officials as they found that India, with a wide prevalence of communicable disease, was a fertile field for medical research. The important fields studied were the role of anopheles mosquitoes in the transmission of malaria by Ronald Ross; the development of vaccine for the prevention of plague by Haffkine; studies on trypanosomes filaria by Lewis; investigations on spirillum of relapsing fever by Van Dyke Carter; cholera by Macnamara and Cunningham; and snakes and snake venoms by Fayrer. A string of Pasteur Institutes began to be established from 1900 onwards. Donovan working in Madras Medical College demonstrated the presence of a parasite, christened as *Leishmania donovani*, in the spleens of kala-azar patients. Among Indian scientist, Brahamachari discovered Ureastibamine in 1920 as a specific treatment for kala-azar. Rogers demonstrated the effictiveness of emetine in the treatment of amoebiasis.

In 1911, the Government of India established the Indian Research Fund Association to promote scientific medical research in India. This Association, for over 30 years, sponsored schemes of research on malnutrition, malaria, rabies, plague, cholera, leprosy and kala-azar. Some of the centres where such work had started developed into institutes. The

Malaria Institute of India was set up in 1926 by the Central Malaria Bureau of Kasauli and entrusted with the main task of treating malaria and advising the government on anti-malaria measures. Later developments in medical research were the result of the recommendations of the Bhore Committee appointed in 1942. The work of the Association was taken over by the Indian Council of Medical Research (ICMR) in 1949.

Work on many of the communicable diseases caused by bacteria, viruses, protozoans or metazoan parasites was mostly limited to survey and epidemiology, and occasionally about vectors, and invariably about preventive measures. Research workers on leprosy are concerned with the epidemiology of the disease, study of time response to infection with *Lepra bacilli* and *in vitro* cultivation of the bacilli, curative effects with sulphones and other chemotherapeutic agents, the pathology of the peripheral nervous systems and surgical reconstructive techniques. Indian researchers, while awaiting the outcome of these studies on primary prevention of leprosy using vaccines, are undertaking studies for the widespread use of combination drug therapy with rifampicin, clofazimine, dapsone and other chemotherapeutic agents, in suitable combinations to bring down infection load in the community. It is of great concern that nearly one quarter of all leprosy patients in the world live in India and about a fifth of whom are infectious.

Two hundred and sixty million people in India are exposed to the risk of infection with filaria. By blocking the lymphatic channels, it produces the ugly condition of elephantiasis. ICMR is implementing a new integrated strategy for the control of filariasis by which immature vectors will be attacked by a judicial use of bioenvironmental methods, minor engineering, and in selected instances, by the use of insecticides.

With regard to tuberculosis, the work was limited to survey incidence and etiological factors, setting up diagnostic clinics and senatoria, organization of home treatment, BCG vaccination programmes, etc. The ICMR's Tuberculosis Research Centre at Madras, which is a superb example of international cooperation in research, in this case involving British Medical Research Council and the World Health Organization (WHO), discovered in 1959 that ambulatory, domiciliary treatment of tuberculosis is highly effective without the risk of infection of family contacts. By this method, the cost of treatment was reduced considerably and it was possible to extend the chemotherapy of tuberculosis into far-flung areas. A collaborative study between the World Influenza Centre in London and ICMR at Coonoor resulted in the isolation of a prime virus strain, and of analysis of antigenic features of Indian strains of influenza virus. They were used for the preparation of prophylactic vaccine.

Medical research which had shown growth points even in the pre-Independence period has assumed new dimensions because of its important role in national development. The ICMR has established research institutions besides supporting a number of specific projects in various institutions in areas like communicable diseases, fertility control, metabolic diseases, nutrition, health delivery systems and medical engineering. It has also undertaken the scientific evaluation of certain traditional drugs through multicentre clinical trials and pharmacological studies as also studies of occupational hazards specially in small-scale industries, pesticides toxicology, etc.

Occasional occurrence of diseases has led to the identification of viruses as their cause. Cases of encephalitis among children in Vellore and monkeys in a group of villages of Karnataka forest have been attributed to new viruses. The discovery of the disease, now widely known as Kyasanur Forest Disease (KFD) is a significant contribution to the biomedical science. KFD virus, an indigenous virus, is entirely new to science and it is the only disease in which ticks, monkeys and men are involved. The disease is characterized by high fatality rates.

On account of a world-wide drive by the WHO and compulsory vaccination, smallpox has been completely eradicated from India. Studies on all aspects of trachoma, filariasis, venereal disease; hepatitis, hookworm, guineaworm and schistosomiasis have been intensified. With regard to asthma, the roles of allergenic pollen, heredity and adrenocortical function have been studied as also the factors which make asthmatics hypersensitive to certain foods and drugs. Pulmonary eosinophilia is peculiar to India, the clinical features being similar to asthma, but is accompanied by leucocytosis and high eosinophil count. Systematic studies on nutritional anaemia and other haematological problems have been initiated. The therapeutic treatment with folic acid, vitamin B_{12} and iron for these anaemias has been followed in various laboratories.

Thalassemia is quite common and not rare as was earlier believed to be. The association of thalassemia with some of the abnormal haemoglobins has been proved. The incidence of erythocytic glucose-6-phosphate deficiency and its bearing on haemolytic anaemias has been examined. Marked differences in the distribution of blood groups among the people of India were observed. A new blood group called "the Bombay Blood Group" related to the ABO system was discovered. Many more cases of this unique group have been in India.

Population control through the regulation of human fertility is indeed in the best interest of man and the society. Indian scientists are working on broadening the range of choice of methods of contraception. Copper T 200 has been shown to have advantages over Lippes loop; newer, long acting hormonal contraceptives are being investigated. Two novel approaches—the intranasal administration of steroids and the immunological approach to the fertility regulation in the female—are being developed.

Anti-Fertility Vaccines

The regulation of human fertility is the most crucial issue today. Basic and applied research in this field is of particular interest to India for evolving new and more acceptable methods for population control.

A vaccine that protects women against pregnancy as well as disease has been developed by the National Institute of Immunology (NII) in New Delhi. The vaccine has proved effective and safe in animals, rendering them infertile for more than a year. Last summer, NII began tests in 88 female volunteers at five different centres. If these clinical trials are successful, the Department of Biotechnology may soon authorize a wider programme.

The vaccine induces the secretion of antibodies that neutralize a hormone, human chorionic genadotropin (hCG). Released soon after fertilization of an egg, hCG is vital to the process whereby the egg attaches to the wall of the uterus and begins to develop into an embryo; without hCG the egg is shed during the women's next menstrual cycle. The vaccine is made of a sub-unit of hCG. By itself the hCG sub-unit does not induce antibodies, and so it is linked to an immunogenic carrier made of the tetanus and cholera toxoids (toxoids are attenuated toxins that serve as vaccines against specific pathogens).

Research has already shown that when this hybrid antigen is injected into a woman, her immune system produces antibodies that bind to hCG as well as to tetanus and cholera pathogens. The tetanus and cholera toxoids were chosen as carriers for three reasons; the diseases are still wide spread; the vaccines have been administered to hundreds of millions of people and their effects are well known. These effects, lasting for a year or more, are not permanent.

A version of the hCG vaccine in which the tetanus toxoid alone was the carrier was tested in 65 women several years ago. Four injections of the vaccine induced the production of hCG antibodies in 63 of the women for periods ranging from 300 to 500 days without interfering with their normal ovulation or menstrual cycles or affecting them adversely in any other way. Though, the vaccine did produce different levels of antibodies in different women, but in some subjects the levels were not high enough to prevent pregnancy. For this reason the investigators decided to add the cholera toxoid as a carrier for the recent tests. Health officials believe that jointly the tetanus and cholera toxoids should stimulate a greater immune response.

In the current trials women receive three injections at one-month interval and a fourth injection six months later. Ideally, the research will produce a vaccine powerful enough for a single injection to prevent pregnancy for up to a year.

In another significant endeavour towards achievement in the anti-fertility vaccine, the Central Drug Research Institute (CDRI), Lucknow, has developed a safe and effective birth control alternative to pill, the oral contraceptive—Centchromam—which provides moderate protection and does not cause any side effects except prolonged menstrual cycle.

A simple kit to detect pregnancy within one week after conception has been developed at NII also. The kit, India's first biotechnology product, uses the hormone, hCG. The test kit is now being marketed by a leading firm in the United States.

The Post Graduate Research Institute (PGI) in Chandigarh has successfully tried gossypol—a male contracentptive on rats, monkeys and rabbits. The drug, scientifically known as 'polyphenol', inhibits synthesis of LDH enzyme, responsible for production of sperms in the testes. Gossypol, yellow, phenolic pigment extracted from cotton seed, administered in doses of 20 milligram daily to the animals causes moderate infertility by making sperms practically infertile at the end of three months. Human trials of this drug are yet to be conducted.

Anti-Leprosy Vaccine

Large scale trials of indigenously developed anti-leprosy vaccine are going on in the country. Already, about 2,500 healthy household contacts of leprosy patients have been vaccinated, and the figure will reach 40,000 by 1990.

The vaccine, developed in 1979 by Dr. Madhav Deo and his colleagues at the Cancer Research Institute, in cooperation with the Acworth Leprosy Hospital, G.S. Medical College and the Haffkine Institute, all in Bombay, contains gamma-ray inactivated ICRC bacilli, named after the Indian Cancer Research Centre (ICRC), the previous name of CRI. The bacilli are a group of leprosy-derived slowgrowing mycobacteria that have been cultivated repeatedly from human lepromata for the past 30 years. Although the exact taxonomical position of the ICRC bacilli is somewhat uncertain, they supposedly belong to the *Mycobacterium avium* intracellular complex. The fact that the bacilli exhibit antigenic cross-reactivity with *Mycobacterium leprae*, especially with reference to T-cell immunity, the dominant host defence against the leprosy germs, forms the scientific basis for the use ICRC bacilli in the preparation of an anti-leprosy vaccine.

Since 1979, the vaccine has been administered in phase-1 and phase-2 clinical trials to patients with lepromatous leprosy and to healthy subjects in an endemic area. The vaccine enhanced immunity in both patient with lepromatous leprosy and to healthy subjects in an endemic area. The vaccine enhanced immunity in both patient and healthy subjects. It was cleared for large scale clinical trial by the Drug Controller of India for both immunotherapy and immunoprophylaxis in October 1984.

A pilot project conducted during the past three years on about 200 healthy household contacts of leprosy patients shows that the vaccine has no untoward side effects. Fears that lepromin-positive healthy contacts may develop hyper-sensitivity to leprosy antigens resulting in nerve damage have been set to rest.

The objective of the large-scale trials is to make a comparative evaluation of the immunoprophylactic efficiency of the two vaccines containing either ICRC bacilli or BCG by measuring the incidence of all forms of leprosy in the vaccinated groups. To achieve statistically significant data, 40,000 people will be vaccinated. The Maharashtra trial is the first ever large-scale clinical trial of a vaccine containing cultivable leprosy-derived mycobacterial. The vaccine is important for India, which accounts for one-third of the 2 million cases of leprosy world-wide.

Elsewhere in the world, two other large-scale clinical trials have been launched in the past three years using vaccines containing *M. Leprae* from armadilla alone or in combination with BCG. The trials in Venezuela are supported by the World Health Organization, while those in Malawi are supported by LEPRA in the United Kingdom.

Biomedical Engineering and Nutritional Research

A lot of work has been done in the growing area of biomedical engineering. Artificial legs, hands and limbs have been developed and improved upon keeping in view the Indian conditions. Special mention may be made of artificial legs which offer facility for squatting (Jaipur limbs). Many instruments have been developed which are being used in major hospitals of our country.

Nutritional research involves survey of deficiencies both in nature and quantity, their preventive measures and the evaluation of such measures. Malnutrition continues to be an important contributory factor to much of the mortality and morbidity especially in mothers, infants and young children. It has been shown that the diets of children with protein energy malnutrition does not provide sufficient energy, and as a result the entire approach to the control of this form of malnutrition has undergone a radical change not only in India but in other developing countries as well. Nutritional blindness in developing countries, in the form of keratomalacia due to the deficiency of vitamin A is being treated by administering heavy doses of vitamin A (200,000 international units) once in six months to children at risk age between one and five years. Iron added deficiency is common in pregnant women and pre-school children. Ferric orthophosphate is the compound which is added to fortify the common salt. A similar approach has been worked out (common salt fortified with potassiam iodine) for endemic goitre which is due to iodine deficiency, and nutritive value of common as well as uncommon food items available in India is being investigated on a continuing basis. Double fortified salt (i.e. with iron and iodine) is under evaluation. Studies on environmental hygiene and dental health, neurology, mental health, cancer, opthalmology, orthopaedics, and drugs are the concerns of the Ministry of Health and specialised research institutes.

Independent chairs of physiology and pharmacology were first created around 1920 in the Calcutta Medical College and Physiology began to be taught as a distinct non-medical discipline in the Calcutta Science College around this time. From ancient times "Yogis" in India have claimed to have developed voluntary control over automatic activities. To verify this claim some investigations have been made on persons practising "Yoga". The influence of cerebral cortex, hypothalmus, limbic system and other parts of central nervous system on behaviour and autonomic functions have also been investigated. In recent years microelectrode studies to probe into the electrical phenomena in single cells or fibres of various tissues have created world-wide interest. Physiology of mechanoreceptors and related structures using this technique have been studied. A number of investigations have been reported on the factors influencing blood pressure, and physiological effects of acetycholine and adrenaline.

Significant contributions have been made to the understanding of visceral sensory mechanisms and their reflex effects, properties of mammalian nerve fibres, the mode of action of chemical substances on sensory receptors, the fusimotor fibres and pressure pain receptors of muscles and the mechanism of stimulation of aerotic chemoreceptors. Of particular significance is the discovery of the volume and the J-receptors of lungs. It has been shown that the natural stimulus for the aerotic chemoreceptor is oxygen availability'.

Many investigations have been carried out to determine the Basal Metabolic Rate (BMR). Studies were made of the influence of level of dietary proteins on the utilization of orally fed vitamin A and B carotene and on the depletion of hepatic storage of vitamin A in rats. A bound form of nicotinic acid called niacinogen has been isolated from rice and wheat. Many invesigations have been done regarding he biosynthesis of various B vitamins. The enzymic synthesis of N-acetylglucosamine 6-phosphate and UDP-acetylglucosamine in brain has been established. Metabolism of polysaccharides and amino-sugars in the brain confirmed the presence of chondroitin sulphates in the rat brain. A new form of dilatometer for studying the kinetics of reaction between an enzyme and its substrate has been devised. The contraction due to the enzyme hydrolysis of one gram molecule of the substrates was defined as contraction constant.

Many investigators are interested in cardiovascular, neuro and endocrine pharmacology, chemotherapeutics and antibiotics of a variety of plant products. The activity of a large variety of synthetic compounds used as either stimulants, depressants, psychotropic agents, administered either orally or centrally, has been investigated. Studies were undertaken pertaining to activity of drugs on adrenergic mechanisms and adrenergic blocking agents. Several chemical agents have been investigated to modify the effect on acetylcholine of the content of acetycholine in a tissue and also on neuromuscular and ganglionic transmission.

Traditional Medicine Research

An every aspect of traditional culture, arts and crafts suffered during the two centuries of colonial exploitation, the Indian systems of medicine such as Ayurveda and Siddha also suffered a terrible set back. Western medicine which had to its credit a contemporary scientific approach as well as economic and political patronage, overshadowed the Indian systems of medicine not merely in the level of efficacy, but also by a substantial support in modernization and sophistication. During the freedom struggle, and more so after independence, the movement for the revival of Ayurveda and its widespread practice in modern form caught up.

There are about 2,200 Ayurveda remedies considered useful in therapeutics of which the medicinal plants constitute the major part. Since independence, about 200 plants, have been worked out pharmacologically. Products of these plants have been classified in accordance with their effects on central nervous system, heart, blood pressure, coagulation of blood, secretion of fluid, etc. These are quite a few which act as expectorants, myoneural blocking, diuretic, anti-inflammatory, anti-diabetic, anti-fertility and chemotherapeutic agents.

Although the Indian Council of Medical Research (ICMR) had been carrying out scientific studies on indigenous drugs from its inception, other aspects of the various indigenous systems of medicine were, however, neglected. Recognising the need for modern scientific research in this discipline, the Government of India created the Central Council for Research in Indian Medicine and Homoeopathy in 1970. This council branched off into four independent councils subsequently, viz., Central Council for Research in Ayurveda and Siddha, Central Council for Research in Unani Medicine, Central Council for Research in Homoeopathy and Central Council for Research in Yoga and Naturopathy.

Three primary goals of research have been identified in this context. Firstly, established ayurvedic drugs have to be subjected to tests by modern parameters to ensure their efficacy for the diseases for which they have been traditionally prescribed. Secondly, because the system of practice in Ayurveda and Siddha have been shrouded in mystery and secrecy in different parts of the country and the methods of drug production have varied from place to place, it has become essential to standardize the ingredients and the proportions in which they are utilized in the manufacture of a given ayurvedic formulation. Thirdly, in a very important area, it is recognized that like any other science, ayurveda, has to have expanding horizons.

In view of this, the Indian Council of Medical Research has identified eight thrust areas for the seventh plan period. These are: Traditional remedies for anal fistula, viral hepatitis, urolithiasis, diabetes mellitus, bronchial asthma, filariasis, kala-azar and wound healing.

Multicentric clinical trials on *Kshaarasootra* (Ayurvedic medicated thread) technique in the management of anal fistula initiated earlier at two centres, viz., the department of surgery, All India Institute of Medical Sciences in New Delhi and PGIMER in Chandigarh, have been extended to three more centres—Kasturba Medical College in Manipal, Goa Medical College in Panaji and Mahatma Gandhi Institute of Medical Sciences in Sewagram.

In contrast to allopathic treatment which involves extensive surgical intervention necessitating prolonged hospitalization with loss of manhours, the *Kshaarasootra* technique can be used in the outpatient departments (OPDs) as the threads are to be changed at weekly intervals. Further, the patients can attend to their normal work even with the thread in the fistulous track.

In filariasis research, selected traditional remedies are being tested at the department of parasitology of the Central Drug Research Institute in Lucknow. Controlled, double blind clinical trials of the Ayurvedic drug *Shakhotak* (*Streblus asper*) have been initiated at the SCB Medical College in Cuttack, Regional Filariasis Training and Research Centres of the National Institute of Communicable Diseases in Varanasi and Calicut respectively. An open clinical trial has been recently started on the Unani drug *Biskhapra* (a combination of *Trianthema decandra* and *Piper nigrum*) at the Regional Filariasis Training and Research Centre in Rajahmundry.

Researches are being conducted in a various national institutions and a number of traditional remedies are being tested to find a cure to diseases like viral hepatitis, urolithiasis, kala-azar, diabetes mellitus and bronchial asthma.

Meanwhile, a drug isolated from an Indian herb described in ancient Ayurveda will make its debut in the market later this year as a potent remedy for high blood cholesterol and other diseases. Guggu lipid, a semipurified substance from the resin of the plant Gum guggul is now undergoing final clinical trials in the country. Researchers say it will be second major contribution of Ayurveda to modern medicine since the introduction of an anti-hypertensive drug, reserpine, a gift from Ayurveda nearly 30 years back.

Gum guggul had traditionally been used for treating arthritis and inflammation. But its role in reducing blood cholesterol was first discovered way back in 1964 by Dr. G.V. Satyawati, a researcher of Banaras Hindu University and now a senior officer in the Indian Council of Medical Research.

A herbal treatment for bone fractures and joint dislocation introduced a century ago has become extremely popular in India. This treatment is offered by a team of seven men known as 'Puttur bone setters' in Esalapuram, 1.6 kilometres from Puttur, a small town in the south Indian state of Andhra Pradesh. On an average some 250 patients are treated each day by bone setters. Patients come from all over India and even abroad. The broken bones are set the same day. X-rays are not required. Patients pay a registration fee of one rupee and doctors fee is not compulsory. Over the past 100 years several thousands have been treated with rare reports of failures.

High-Tech Babies

In the area of test tube babies, with the birth of first authentic test tube baby at the KEM Hospital in Bombay in 1986, India has joined that small group of countries in the world, which has the expertise to produce babies using the 'in vitro' fertilisation and embryo transfer (IVF-ET) technique. The technique has been developed by the research scientists of the Institute for Research in Reproduction (IRR) in collaboration with the doctors of the KEM Hospital in Bombay.

The technique involves transfer of egg captured before ovulation to an external environment—a test tube or a dish comparable to a fallopian tube—and fertilisation there with the male sperm in controlled environment of an incubator. After 48 hours, the fertilised egg is returned to the uterus by an insertion through the cervix, thus by passing the oviduct. It then grows like any normal foetus. In other words, IVF-ET is taking an egg from a fertile woman and sperm from the fertile man and enticing these microscopic entities to merge into living embryo ready to be implanted in a waiting womb. Timing and refined surgical skill are key factors in this.

The other method, artificial insemination, is even simpler. In this a live sperm is injected into a woman's uterus at the time of ovulation. Yet another method transferring an embryo from a female donor to an infertile woman—otherwise capable of carrying a child—has also been tried. IVF-ET is most commonly used in cases of blocked or damaged fallopian tubes (oviduct). Since the technique uses a married couple's own sperms and eggs, no serious legal questions arise. But the possibilities of creating problematic legal questions in this method are endless. For example, babies are being born in advanced countries to genetic parents who have never met.

The IVF-ET technique is quite expensive. If the technique is carried out in a private hospital it may cost about Rs. 60,000. But at a public hospital one may have to pay only for the hormones which are usually imported. The technique carries basic risks like the development of chromosomal abnormalities during test tube fertilisation. The other disadvantage is that due to external hormone administration the woman's internal hormonal balance gets disturbed and this may lead to complications.

It prevents the embryos from being rooted into the walls of the uterus. However, this difficulty has been overcome by the scientists. They have developed a technique of freezing the embryo at minus 200 degree Celsius in liquid nitrogen for about 30 days. During this period the levels of hormones in the woman's body return to normal and she is ready to receive the embryos.

Indian doctors believe that wider use of the IVF-ET technique can improve understanding of reproductive biology, genetic diseases and innovate newer methods of contraception. The allure of embryo transfer lies in its potential to rapidly replenish any species on the verge of extinction as well as the genetic quality of the human species.

In India, work on embryo transfer began in only 1980s when Dr. Indira Hinduja, senior gynaecologist at the KEM Hospital, worked in collaboration with the Institute of Research in Reproduction. She worked with hamsters and then with human beings. She claims a success rate of 10 to 15 per cent, and is confident of attaining 40 per cent.

Though nearly three thousand test-tube babies have been born the world over, the IVF-ET technique is complicated and the success rate fairly low. Techniques may vary, but the basic principle involves the extraction of a mature egg (oocyte) from a woman's ovary and its fertilization in a petridish by a sperm. After the embryo develops to the four-to-eight cell stage, it is transplated into the woman's uterus. Several gynaecologists in the country, including Dr. Hinduja, are about to experiment with another method, appropriately called Gamate Intra Fallopian Tube (GIFT) transfer which has been successfully tried in the western countries.

In this technique, the laparoscopy is timed just before ovulation. The husband's semen is collected one hour prior to the laparoscopy. The healthy sperms are separated and kept ready. Through laparoscope the female egg is retrieved and to a drop of the husband's sperm fluid is added. This egg is then returned into the fallopian tube at the same sitting. The fertilized egg then follows the natural course to the wall of the uterus and gets implanted.

GIFT transfer has its own advantages. A number of steps in the process are automatically omitted. The ovary need not be stimulated by hormones. The retrieved eggs need not be placed in an incubator, for the egg that comes out is already mature. It is also not necessary to keep the embryo in an incubator outside the body to achieve 8 or 16 celled stage. The technique helps the natural process and this is of a better quality. It is used on women having damaged tubes but who show cervical hostility and in cases where the husband's semen shows lower sperm concentration than the normal.

Doctors say they would welcome a comprehensive legislation to curb possible abuse of the technique and remove potential legal entanglements. Major reproduction centres in the world have their own ethnic standards. In Britain, in July 1984 a Government appointed committee recommended setting up of a statutory authority to monitor and control the use of IVF-ET sperms and egg donations and other aspects of fertility research. The penal also proposed a ban on surrogate motherhood agencies. However, the debate ends at much the same intractable point as the argument over abortion: When does a tiny mass of living cells ceases to be mere biological matter and become a fully entitled human being.

Besides the IRR and the AIIMS, a Calcutta hospital is also engaged in studies on test-tube babies, while two doctors who have learnt the IVF-ET technique abroad are planning to set up a private clinic in Bombay in view of the increasing demand for test-tube babies. Dr. Subash Mukherjee of Calcutta claimed in 1976 that he was able to produce the first test-tube baby in India, but the medical community did not accept it.

Laser Surgery

Lasers, the device which produces a coherent beam of light intense enough to vaporise the hardest material ever known, are finding increasing applications in India for "spot welding" of bleeding vessels in the retina of patients with a variety to eye diseases and cut, vaporise and seal malignant brain tumours located deep inside the brain or in the spinal cord of cancer patients.

In the three major hospitals of Delhi, laser beams are being used to destroy malignant tumours located inside the brain or in the spinal cord. The technique has been tried on 600 patients and a majority of the cases, has proved successful. Laser surgery, which causes far less trauma, is being tried by doctors of the G.B. Pant Hospital; All India Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital in New Delhi, as well as in the Christian Medical College at Vellore and the National Institute of Mental Health and Neurosciences in Bangalore.

Ophthalmologists at Dr. Rajendra Prasad Centre for Ophthalmic Science of the All India Institute of Medical Sciences in New Delhi and seventeen other major hospitals in the country are doing laser surgery to halt developing blindness and improve vision by controlling bleeding from ratina vessels. Laser application in eye surgery is now on the increase in the country. It is providing new ways of treating complicated retina diseases like glaucoma and cataract.

By selecting the appropriate wavelength and intensity of laser lights surgeons can now perform different kinds of operations. The depth of penetration of the beam and whether it vaporizes or coagulates cells can be controlled by regulating the rate at which the light is absorbed. Absorption of lasers is determined by the wavelength, preferentially. For example, water molecules absorb the energy of carbon monoxide lasers selectively absorbs the light argon lasers which are, therefore, used to coagulate blood cells and control bleeding.

The argon laser is being used in the country to treat chronic glaucoma, the disease of the eye characterized increased fluid pressure within the eyeball Neodymium-Yag laser is being used in treating acute glaucoma in which fluid pressure in the eyeball suddenly goes up and even in a few hours a person goes blind. Treatment by medicine is followed after laser surgery to avoid future attacks.

LIST OF MEDICAL INSTITUTIONS WHERE LASER FACILITY IS AVAILABLE

S. No.	Name of Institution	Type of laser (Argon/Yag)
1.	Department of Ophthalmology, King George Medical College, Lucknow	Argon
2.	A.M.U. Institute of Ophthalmology, Aligarh	Argon
3.	Medical College, Rohtak	Yag
4.	Lady Harding Medical College, New Delhi	Argon
5.	Maulana Azad Medical College, New Delhi	Argon
6.	Christian Medical College, Ludhiana	Argon

S. No.	Name of Institution	Type of laser (Argon/Yag)
7.	M.G.M. Medical College, Indore	Argon
8.	R.N.T. Medical College, Udaipur	Argon-Krypton
9.	S.D.M. Hospital-cum-Medical Research Institute, Jaipur	Argon
10.	M.J. Institute of Ophthalmology Ahmedabad B.J. Medical College	Argon
11.	K.E.M. Hospital, G.S. Medical College, Bombay	Argon-Krypton
12.	Bombay Hospital, Bombay	Argon
13.	DEU Institute of Ophthalmology, Manipal	Argon
14.	Rajendra Prasad Centre for Ophthalmic Science, AIIMS, New Delhi.	Yag/Argon
15.	Medical Research Foundation 10, College Road, Madras	Yag/Argon
16.	ASP Pavlov Hospital under Sahibabag Bridge, Ahmedabad	Argon
17.	Army Hospital, Delhi Cantt.	Argon
18.	Wellingdon Hospital, New Delhi.	Argon

Among the retinal diseases which are being treated by Argon laser and Neodymium Yag laser are diabetic retinopathy-proliferative and non-proliferative, sub-retinal non vascular membrances (SRNV), central serous retinopathy, peripheral retinal diseases—vescular and retinal tears. A major advantage of lasers is that they can remove abnormal tissues, while causing minimal damage to adjacent normal tissues. For making surgical incisions in the skin ordinary scalpels make cleaner and faster cuts but laser surgery has fewer complications like infection.

Kidney Transplantation

From the stage of tentative experiment in kidney transplantation, India has reached the stage of routine therapeutics. In hospitals all over the country the result of kidney graftings has improved, and the number of transplants performed each year is increasing.

The doctors have established the methods of selection of living and cadaver donors. They say the current methods of immunosuppression are fairly successful although they have some drawback; the monitoring of the grafted patient still depends on clinical and biochemical data rather than on the study of the immunologic situation. although in the final analysis, it provides the only true criteria for the intelligent direction of the therapy.

The first step in kidney transplantation is selection of healthy donor which is based on two main techniques, serologic determination of the leukocyte or HLA antigens and mixed culture of lymphocytes from donor and recipient. Using these methods, specialized laboratories like All India Institute of Medical Sciences (AIIMS) can now determine the presence or absence of every one of the HLA antigens in a given subject. It is presumed that perfect compatibility is achieved when donor and recipient have no detectable antigenic difference and both carry the same for HLA antigens. This overcomes the rejection phenomenon—the basic problem of organ transplantation. Usually in two weeks' time, the rejection process develops and reaches the peak. The results of this rejection is wide spread infiltration of the transplant with lymphocytes with microvascular changes which result in failute of the blood supply of the transplant.

The choice of donor is based on several factors like age, health and his relationship with recipient. It is not enough to be satisfied that the donor is in full possession of his faculties and has no physical disease. It is essential, particularly in case of a volunteer donor, to be certain that he is entirely free in his decision and has a genuine wish to donate a kidney after being made fully aware of the risks and of the fact that there is no guarantee that transplantation will be successful.

Once a kidney is removed from the donor, there are two methods used by Indian doctors, to keep it alive or at least avoid irreversible damage. They are to minimize metabolic needs as far as possible and to increase the resistance of the tissues to the absence of vital substances; or, alternatively, to supply the essential nutrients artificially. Experts say it is not yet possible to preserve permanently organs such as the kidney either by freezing, the first method, or by continuous perfusion at —37°C. The best results have been achieved by a compromise which consists in greatly diminishing metabolism, usually by moderate hypothermia (surface cooling) so that only very small amount of nutrients have to be supplied to the organs by perfusion. The doctors are using several immuno-suppressive agents like azathioprine (Imuran) and cyclosporin to prevent organ rejection. They are also using other methods of non-specific immunosuppression like total body radiation, radiation of blood, local radiation ribonucleases and various other substances to suppress the recipients' immune system.

The removal of donor's kidney and the preparation of the transplant bed in the recipient are carried out simultaneously by two surgical teams in adjoining operating rooms. The work of two teams is synchronized so that the moment the kidney is removed the recipient team is ready to use it. The donor operation is begun first because it takes longer than the preparation of the transplant bed in the recipient. The techniques of actual transplantation are preparation of the kidney bed and the recipient vessels, revascularization of the kidney and restoration of urinary tract continuity. The whole operation takes three to four hours. Besides AIIMS, there are about eight hospitals namely Christian Medical College and Hospital, Vellore; Post Graduate Institute (PGI) Chandigarh; Jaslok Hospital, Bombay; Apollo Hospital, Madras; Osmania Medical College, Hyderabad; KEM Hospital, Bombay, where kidney transplantation is being performed almost on a regular basis. Private hospitals carry out more operations than government hospitals in the country due to several reasons.

The average cost of renal transplantation varies from Rs. 20,000 to Rs. 1,00,000 with a maintenance cost of Rs. 300 per month. But it is still cheaper than the average cost of Rs. 4,000 for maintaining dialysis in a hospital. In government hospitals the transplantation cost is cheaper than in private run hospitals.

This treatment has come under close scrutiny by the public. It is inevitable that methods used by the medical and scientific community to procure and distribute organs, to decide who receives transplant, and to determine who performs transplants will come under increasing government surveillance and regulation. Adequate organ procurement and facilitation of organ sharing on an international basis will necessitate increasing involvement. Everyone involved in transplantation has a moral responsibility to work for the general distribution of this scarce resources to ensure equal access for all those in need regardless of social standing or financial resources.

In India several hospitals use cyclosporin in kidney transplantation particularly when the donor is not related to the recipient. The drug is mixed with olive oil which carries it across the intestine and into the blood stream. Cyclosporin must be taken for life. According to Sandoz, kidney patients given cyclosporin have more than 80 per cent chance of living through their first year compared to 50 per cent without the drug.

Referring to mechanism of action, researchers say, two types of white blood cells inthe body tryto repulse intruders; B-cells and T-cells. B-cells produce antibodies in response to antigens, the identity tags that tell the body whether matter is its own or foreign. B-cells are particularly important in defending the body against bacteria. T-cells have several roles. One is to destroy tumours; another to reject grafts. Rejection begins when a chance of message is passed along to the relevant T-cells after foreign antigens have been recognised. This is where cyclosporin comes in. Nobody understands exactly why but the drug appears to disarm the relevant T-cells by blocking the innercellular messengers which tell them to attack. Because cyclosporin seems to affect T-cells only, the B-cells are left intact to attack bacterial infection after the transplant.

Space Research

THE INDIAN space programme which began in a modest way in 1963 is now set to take on complex missions like building Polar Satellite Launch Vehicle (PSLV), Indian Remote Sensing Satellites (IRS) and indigenous INSAT satellites.

Within ten years after the launch of the first Indian scientific satellite Aryabhata, designed and fabricated by engineers of the Indian Space Research Organisation (ISRO) from a Soviet cosmodrome in 1975, Indian space scientists have built two earth observation satellites Bhaskara I and II, and an experimental communication satellite APPLE, besides four small Rohini satellites for the indigenous SLV-3 launch vehicle. The principal objectives of the space programme are to develop indigenous competence in designing and building sophisticated hardware involved in space technology including rockets and satellites for scientific research and practical applications.

The space scientists are also engaged in creating the country's own launch facilities by building satellite launch vehicles. Four SLV-3s (Satellite Launch Vehicle) have been tested for putting the Rohini satellites into orbit. The first successful launch in July 1980 put India firmly on the space map to become the sixth nation in the world to have satellite launch capability. Plans are on to build rockets to launch heavier satellites.

There are several centres and units in the Department of Space which carry out the different aspects of the space programme. The Vikram Sarabhai Space Centre (VSSC) in Trivandrum is concerned with all aspects of launch vehicles technology. The ISRO Satellite Centre (ISAC) at Bangalore is engaged in the design and development of satellites. The Space Applications Centre (SAC) at Ahmedabad deals with the research aspects of space applications such as communications and remote sensing and develops satellite payloads for such applications. The Sriharikota Range (SHAR) is the centre where satellite launches and ground operations take place. The PSLV Complex at Valiamala caters to the development and testing of the Polar Satellite Launch Vehicle (PSLV). The Liquid Propulsion Systems Unit (LPSU) at Valiamala, Mahendragiri and Bangalore deals with the development and testing of liquid propellant rocket engines and related systems. The National Remote Sensing Agency (NRSA) at Hyderabad has earth stations to receive data from remote sensing satellites and sophisticated computer systems and photographic facilities to process the data for supply to users. The Physical Research Laboratory (PRL) is one of the places where basic research is carried out in space research. The ISRO Telemetry, Tracking and Control (ISTRAC) unit at Bangalore monitors and controls low earth orbit satellites, while the Master Control Facility at Hassan does the same function for the INSAT satellites in geosynchronous orbit.

Satellite Technology

Astounding advances in satellite technology in the country have made possible efficient communications at reasonable cost specially in backward and inaccessible areas, accurate and efficient weather forecasting and remote sensing of living and non-living natural resources.

The development of satellite technology at the ISRO Satellite Centre (ISAC) in Bangalore has evolved through the building and successful launching of eight satellites, both scientific and technological, during the last three decades. This has resulted in ISRO establishing capability in the design and development of simple spinning satellites and the more complex three axis stabilised satellites, both for the near earth as well as geostationary orbits.

As a preparatory step in developing satellite technology, ISRO took the course of building a satellite containing scientific experiments and having it launched by the Soviet Union. Thus, the launch of Aryabhata, the first Indian satellite in April 1975 marked an important step in building competence in satellite technology. With the experience gained in Aryabhata, Bhaskara I was launched in June 1979, again from the USSR. Bhaskara II was launched in November 1981. Bhaskara was similar to Aryabhata in many respects; the main difference lay in the payload. Bhaskara carried two TV cameras in visible and infrared bands, microwave radiometers, tape recorders, data collection platforms and other equipment.

The Rohini Satellites (RS) have been launched into low earth orbits by India's own launch vehicle, viz., SLV-3. So far three Rohini Satellites have been orbited, the first one (RS-I) was basically a payload which evaluated the performance of the fourth stage of SLV-3, the second (RS-DI) carried a landmark sensor as its main payload; the third one (RS-D2) carried a two band imaging system called the SMART Sensor, which could identify and image certain land features.

Yet another significant milestone was the successful launch of the Ariane Passenger Payload Experiment (APPLE), India's first experimental communication satellite on the European Ariane launch vehicle, APPLE has been used successfully to conduct experiments in communications relating to domestic communication, radio networking, data relay, remote area communication, etc. APPLE had two C-band transponders. APPLE gave ISRO experience not only in building a 3-axis stabilised geostationary satellite, but also in orbit raising and geostationary station keeping. Many key technology elements were developed indigenously for the satellite.

Under the Stretched Rohini Satellite Series (SROSS) Project, spacecraft weighing 150 kg, to be launched by the Augmented Satellite Launch Vehicle (ASLV), are being designed. The basic spacecraft has a multimission capability for operation in either a spinning or a three axis stabilised mode. The first of these satellites (SROSS-1) is scheduled for launch in 1988.

Indian Remote Sensing Satellite (IRS-1A) went into orbit on March 17, 1988, making India the fifth nation and the first developing country to have its own operational remote sensing satellite in space. IRS-1A, launched from the USSR, carries two linear imaging self-scanning cameras that will take pictures of 148-km wide areas in four different colours with a spatial resolution of 38 and 76 metres. The satellite is designed to operate for minimum two years and being sun-synchronous will fly over the same point of the earth at the same local time once in 22 days. It will be used to generate resource information in vital areas of national development like agriculture, forestry, geology and hydrology. The IRS programme is intended to be a key element of India's ambitious National Natural Resources Management System (NNRMS), which is now being established.

The INSAT system is a multipurpose satellite system catering to telecommunications. TV broadcast, meteorological imaging and data collection, etc. INSAT-1 system is being procured from abroad according to Indian specifications. The second generation INSAT-2 system is to be designed and developed indigenously. This will be a three spacecraft system in the geostationary orbit. As a precursor to this system, two INSAT-2 Test Satellites are being designed and developed at the ISRO Satellite Centre, the first of which is to be launched in the 1990-91 period. This will have 18 transponders in the C band/extended C band, two S-band high power transponders, one data relay transponder and a search and rescue payload (SAR) in the communications segment and a Very High Resolution Radiometer (VHRR) in two spectral bands for meteorological imaging. The satellite uses a solar array on one side, and a long boom with a solar sail

PSLV
ISRO
INDIA

on the other side to counterbalance the solar wind pressure on the solar array. In orbit, with the deployment of the solar sail, the spacecraft will be 23 metres long.

Launch Vehicles Technology

The rocket programme in India began with the establishment of the Thumba Equatorial Rocket Launching Station (TERLS) in 1963 for launching sounding rockets equipped with instruments to conduct meteorological or scientific observations. Initially foreign rockets were used and later on the Rohini Sounding Rockets (RSR) were developed indigenously. Currently being used are RH-200 which can lift a payload of 6 kg to 60-90 km. RH-300 with a payload of up to 50 kg for altitudes of 140-150 km, and RH-560 with payloads of 100 kg for altitudes up to 350 km.

India's first satellite launch vehicle was the SLV-3. The first successful launch placed a 35 kg RS-1 satellite into a low earth orbit in July 1980. This was the culmination of about seven years of developmental effort. The next two launches of SLV-3 took place in 1981 and 1983. The 22.7 metre long SLV-3 was a four stage solid propellant vehicle with a launch weight of 17 tonnes. The first two stages used 15CDV6 steel for their casing, and the last two had bodies made from fibreglass. The equipment bay seated on top of the third stage contained inertial guidance systems to steer the vehicle along a predetermined trajectory, and the electronics for telemetry, telecommand and tracking. Attitude control of the vehicle was achieved using secondary injection thrust vector control (SITVC) and fin tip control (FTC) for the first stage, bipropellant reaction control system (RCS) for the second stage, monopropellant RCS for the third stage and by spinning the stage for the fourth stage. The SLV-3 programme was terminated after four flights.

The Augmented Satellite Launch Vehicle (ASLV) is designed to place a 150 kg satellite (SROSS) into a 100-km orbit. This constitutes an addition of two first stage rocket motors as strap-ons to the sides of the SLV-3 first stage. The heat shield, which protects the satellite from the heat generated as the vehicle speeds through the dense atmosphere, has been made large to accommodate the large spacecraft. In addition, a closed loop guidance system incorporating a stabilised platform inertial navigation system (SPINS) and a microprocessor based navigation and guidance computer has replaced the open loop guidance system used in the SLV-3 in order to achieve a more accurate control of the trajectory. Some of the other changes include a change over to S-band frequencies from VHF to comply with international regulations for radio transmissions, use of KEVLAR fibre for the fourth stage body in order to increase the payload capability, etc. The lift weight of ASLV is 39 tonnes and its height is 23.5 metres. The second flight of ASLV is scheduled for mid-1988. The first flight of ASLV failed in 1987 because of a technical snag.

ISRO has already started the design and development of a Polar Satellite Launch Vehicle (PSLV) to place a 1,000 kg satellite in a 900 km near polar sun synchronous orbit. PSLV is expected to weigh 275 tonnes at lift off and will be 47.2 metres tall. This is targetted for a first flight in 1989. PSLV will have five stages. The first stage has a diameter of 2.8 m and carries 125 tonnes of solid propellant. This is flanked on the sides by six strap-on boosters derived from the SLV-3 first stage. Attitude control for both these stages is accomplished by secondary injection thrust vector control (SITVC) and bipropellant reaction control system (RCS). The second stage is a liquid engine using 37.5 tonnes of liquid propellants. Control is achieved by gimballing of the engine and hot gas thrusters. The third stage uses solid propellant and has a flexible nozzle for attitude control. The fourth stage uses two liquid engines. A large complex has been established at Valiamala for developing and testing PSLV elements. The liquid engine tests are to be carried out at the newly established test facilities at Mahendragiri.

India's plan for the near future is to be able to develop indigenous capability to launch INSAT type satellites into the geostationary orbit. Studies are going on in pursuit of this goal to design a geostationary satellite launch vehicle (GSLV). This would include the design and development of a cryogenic rocket engine using liquid hydrogen and liquid oxygen as propellants.

Satellite Communications

Long before positioning India's own communication satellite in the geostationary orbit, an intensive experiment was conducted to assess the technological as well as the sociological aspects of satellite TV broadcast. This was the Satellite Instructional Television Experiment (SITE) which ran from August 1975 for a year. For this purpose, a collaborative programme was organised between the US National Aeronautics and Space Administration (NASA) and ISRO, and NASA's geostationary communication satellite ATS-6 was suitably repositioned for rebroadcasting TV programmes to about 2,400 villages in several Indian states, using programmes from Ahmedabad and Delhi The object of this complex mass communication experiment was to demonstrate the use of direct broadcast of TV programmes for rural development in the fields of agriculture, health, family welfare, education and national integration. This programme was hailed all over the world as a successful application of satellite technology for human development.

Another major preparatory satellite communication experiment was the

Satellite Telecommunications Experiment Project (STEP) which was conducted for two years from mid-1977. Using the Franco-German geostationary communication satellite, Symphonie, STEP gave ISRO valuable experience in integrating satellite channels into terrestrial networks. A road transportable terminal and an air liftable terminal were built and used for demonstrating the use of satellite communications for remote areas and emergencies.

Originally envisaged as a two satellite system, the Indian National Satellite System (INSAT) is a multipurpose operational system for domestic telecommunication, meteorological earth observations, nation wide direct telecasting, radio and TV programme distribution for rebroadcasting and networking. INSAT-1 is India's first operational space system consisting of two satellites, a mission control centre, a telecommunication ground network consisting of 31 ground stations, a meteorological ground segment consisting of a data reception and utilisation centre, several secondary data utilisation centres and 100 data collection platforms, a radio networking and TV ground segment, disaster warning terminals, etc.

The INSAT-1 satellites are manufactured abroad according to Indian specifications. Each spacecraft contains twelve 36 MHz wide 6/4 GHz transponders for telecommunications, two 36 MHz wide 6/2.5 GHz high power transponders for TV broadcasting and radio and TV distribution, a very high resolution radiometer (VHRR) for meteorological earth observation and a data relay transponder operating in the 0.4/4 GHz frequency bands.

Launched in April 1982, INSAT-1A was unfortunately lost in September 1982 owing to a complex interplay of unforeseen events and relatively minor spacecraft deficiencies, each of which under normal circumstances, was extremely unlikely to cause a catastrophe. The operating capability of the INSAT-1 system was restored by late 1983 with the launch of INSAT-1B, which incorporated modifications in the light of the findings of the INSAT-1A fault enquiry committee. INSAT-1C is planned for launch in 1988 and would complete the total capacity of the INSAT-1 system. INSAT-1D, which is to replace the aging INSAT-1B, is scheduled for launch in 1990.

INSAT is an operational system. Continued availability of the space segment capabilities on an assured and no-break basis is of paramount importance as delivery of national telecommunication, broadcasting and meteorological services are dependent on it in various measures—some partially, some totally. For this, the government has formulated a long term INSAT space segment replenishment strategy. This strategy is predicated on indigenous design and fabrication of future INSAT-2 spacecaft.

Remote Sensing

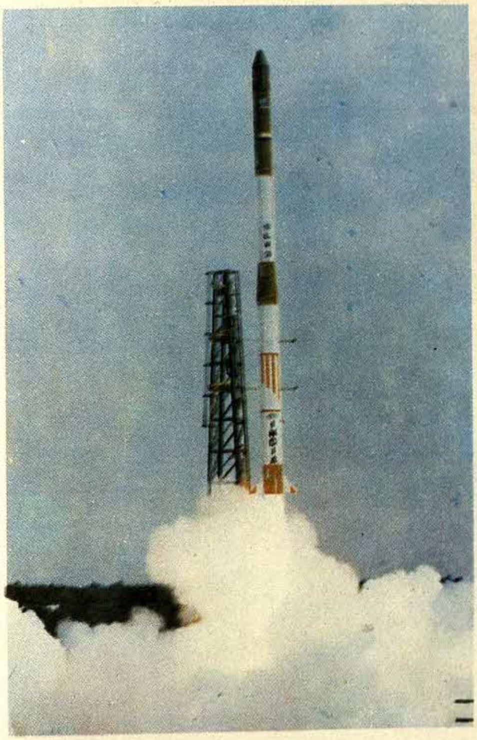
The Indian Remote Sensing Programme aims to develop technology and skills required to supply remotely sensed data from spacecraft, aircraft and other platforms and to demonstrate the utility of such data for efficient management of natural resources and for environmental monitoring.

A number of aircraft based remote sensing surveys have been carried out for land use studies, soil surveys and agricultural monitoring. Further, data from the US LANDSAT series of remote sensing satellites and the weather satellites (NOAA), along with aerial survey data have been utilised for geomorphological mapping, soil survey studies, land use studies, forest inventory and management and studies on flood mapping, snow melt forecasts, agricultural inventory, crop yield estimates and water resources survey and management.

The earth station established near Hyderabad by the National Remote Sensing Agency (NRSA) has been acquiring and distributing data from the LANDSAT satellites. It is also receiving data from the French SPOT satellite and the Indian IRS-1A. Data from the earlier two Indian earth observation satellites Bhaskara I and II have been utilised for several studies.

The Space Applications Centre (SAC) at Ahmedabad is the nodal centre for research for the Indian remote sensing programme, and the operational part of the programme is carried out through NRSA. A major national effort under the aegis of the Planning Commission for the use of the remote sensing data has been organised under the National Natural Resources Management System (NNRMS). The Regional Remote Sensing Service Centres (RRSSC) are being established in the country with sophisticated computers and photographic equipments, apart from laboratories managed by the state governments to process and aid in the utilisation of remote sensing data. During the Indo-Soviet manned space mission, multihand and cartographic cameras collected photographs of selected Indian regions. The mission called Pavan lasted for about five days and provided high resolution photographs which have been used for several studies.

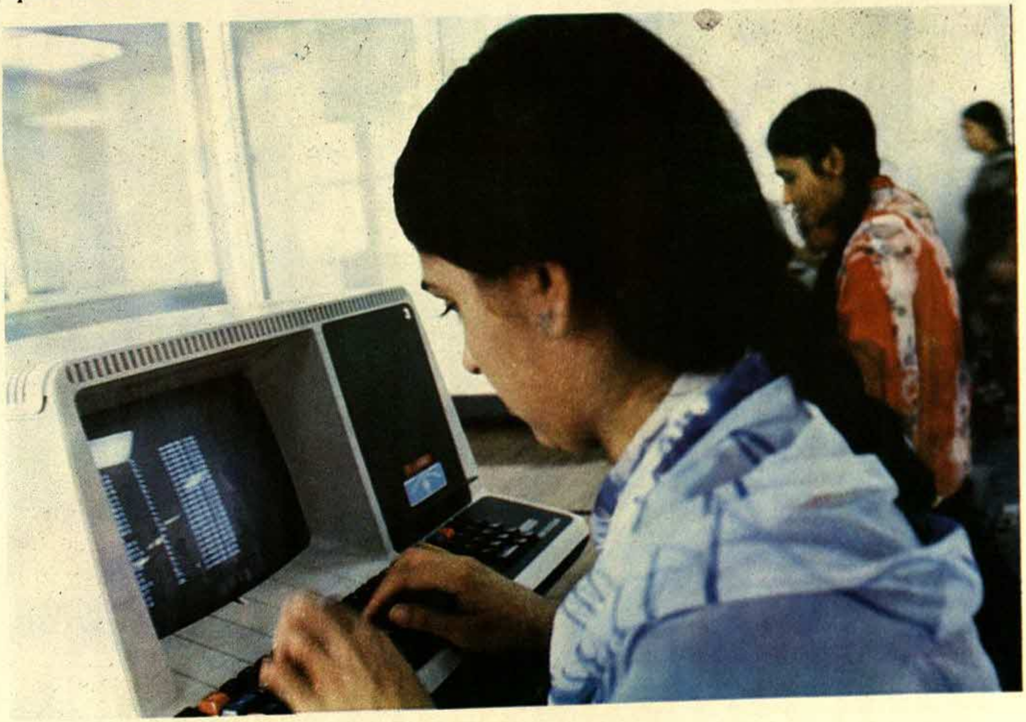
Using satellite data, nation-wide maps have been prepared to indicate forest cover, wastelands and ground water targets. Major national efforts for afforestation, reclamation of wastelands and optimal use of ground water have been aided by this process. The Department of Space, along with other national agencies and academic institutions, is pursuing various applications in the areas of geology, agriculture, land use, water resources, coastal monitoring, etc.

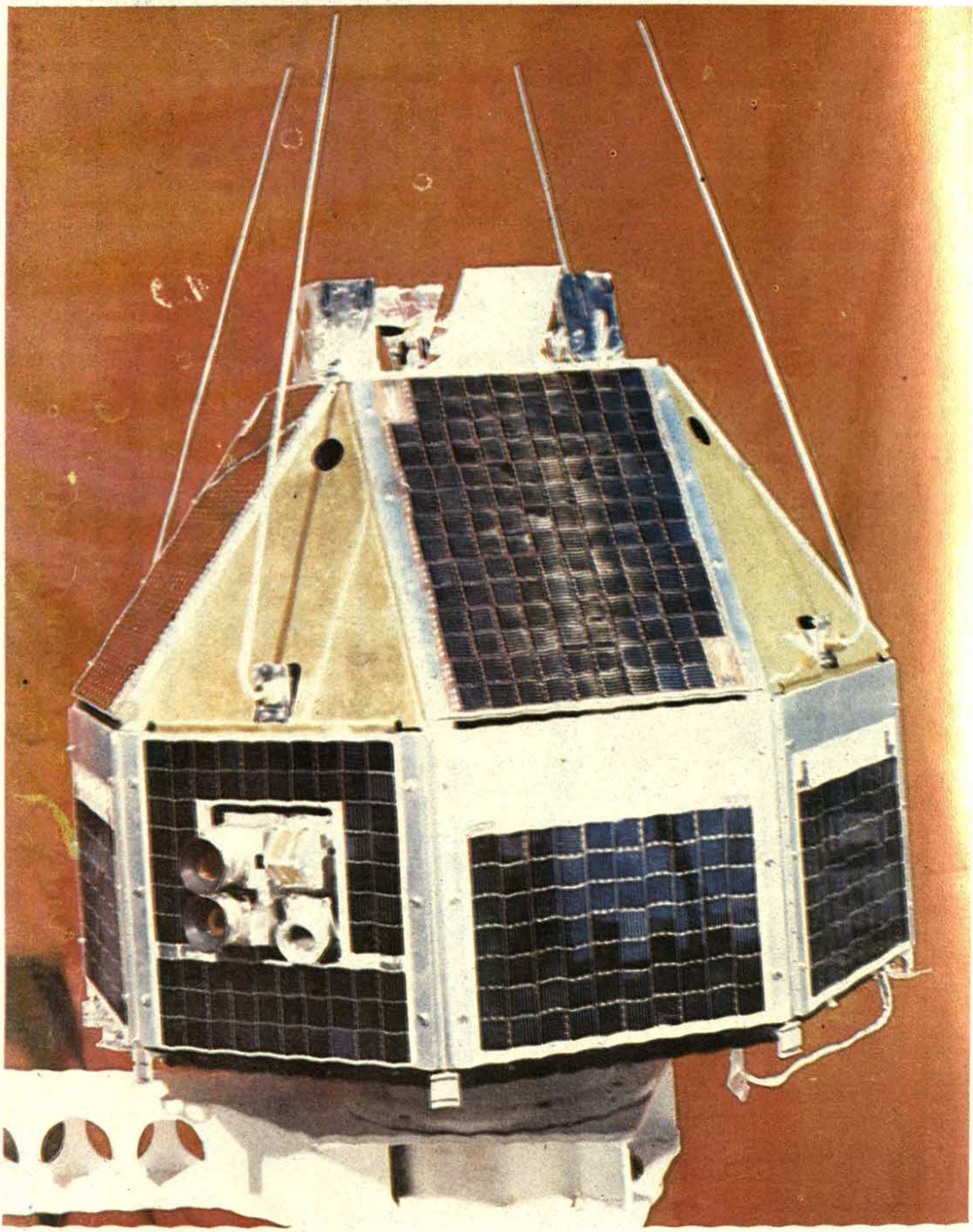


SLV Liftoff

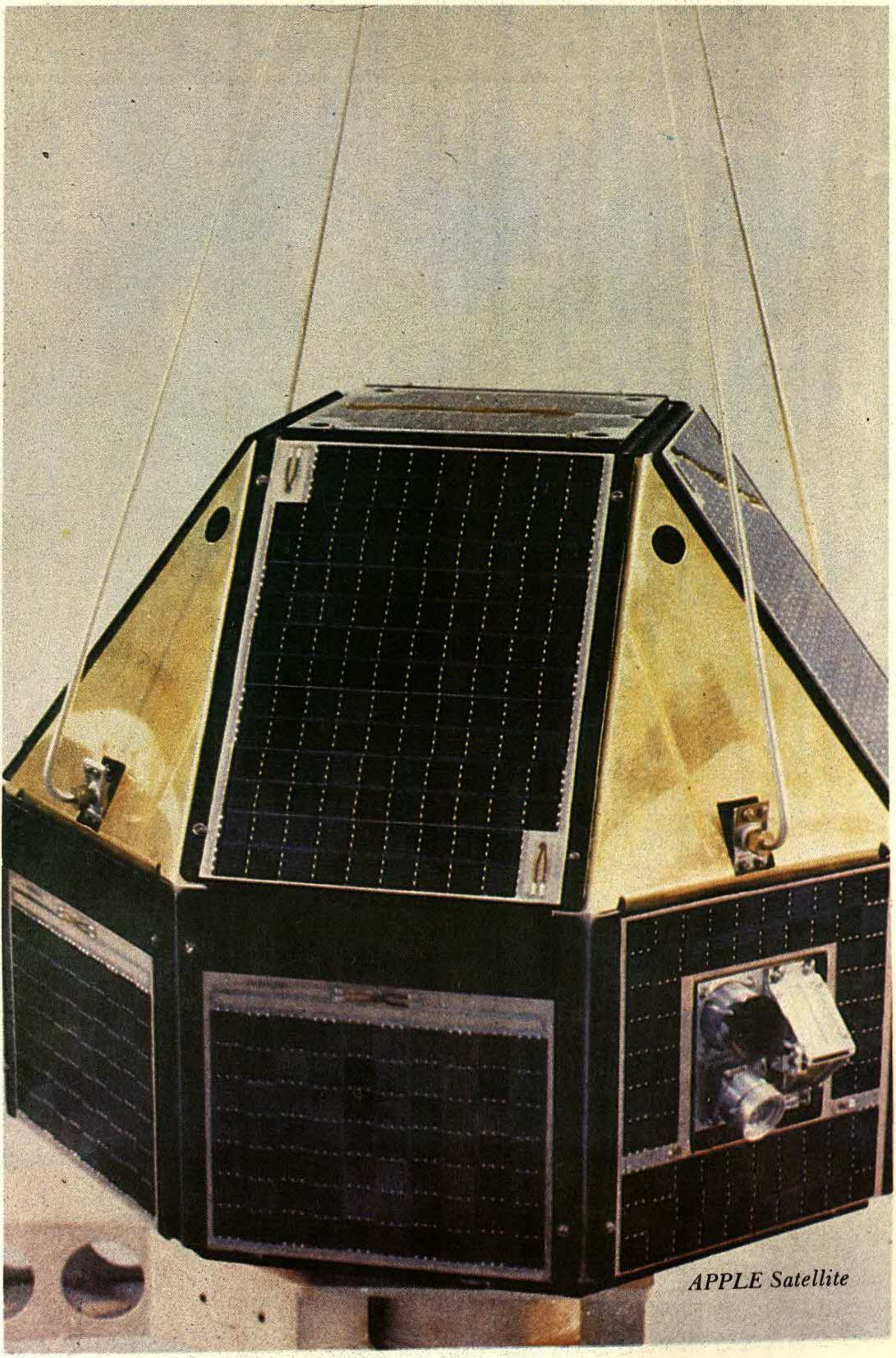
Rocket Launching Pad at Thumba

Space Data Processing at Computer Terminal

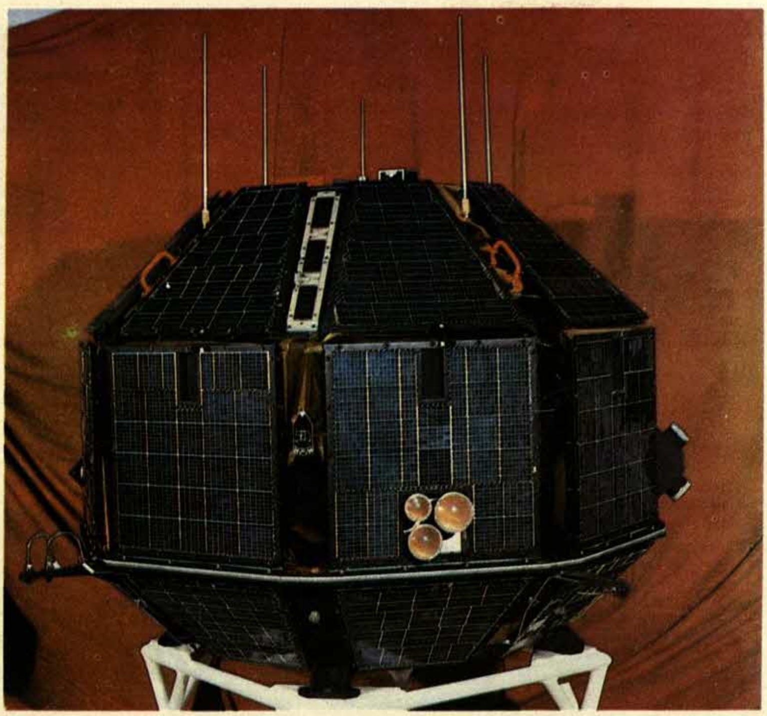




Rohini Satellite

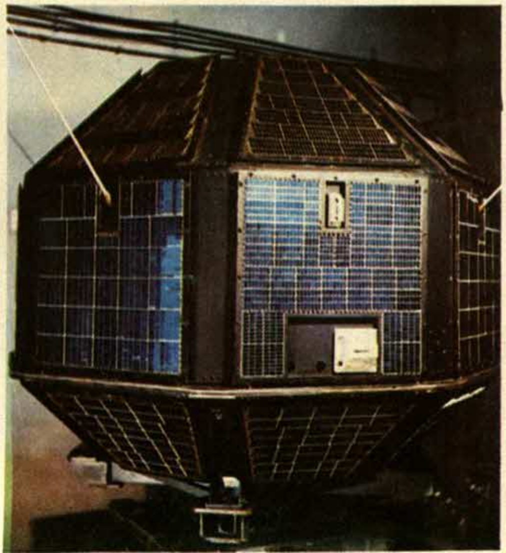


APPLE Satellite



Bhaskara Satellite

Aryabhata Satellite



The studies conducted in India have clearly demonstrated the fact that remote sensing data obtained from orbiting satellites can form the ideal data base for monitoring the environment. The repetitive coverage from the satellites makes it possible to monitor the changes that are taking place. Though the potential of the technique has been understood, much remains to be done before it can be exploited fully. One of the primary requirements is to integrate the information obtained from the satellites with that of the conventional information systems, for which efforts are under way in the country. Besides, remote sensing in the microwave region of the electromagnetic spectrum using active sensors like radar is also gathering momentum in India as in many other countries because of the ability of microwaves to penetrate clouds, operate day and night, etc.

ISRO and NRSA have developed software and hardware technologies for the preparation of colour composites and computer compatible tapes for remote sensing imagery, multispectral additive colour viewer, optical reflecting projector, dual densitometer, colour composite printer, microfiche camera system, analogue image analyser, ground radiometers, etc. Some of these technologies have been transferred to selected Indian industries.

Space Programme—Industry Partnership

(a) *Technology transfer*

In pursuing research and development to meet its goals, the space programme has accumulated a wealth of advanced technology. Nine years ago, ISRO commenced dissemination of know-how to industry. ISRO and NRSA technologies transferred to Indian industries fall under three different end-objective categories: technology transfer primarily for buy-back; transfer primarily for promotion of space applications and space systems utilisation; and transfer for development of non space 'spin-off' applications. Over the years, the transfer of technology to Indian industry has intensified, and the spectrum now comprises speciality chemicals, polymers & minerals, electronics & telecommunications/TV systems, precision electro-mechanical, opto-mechanical and electro-optic instruments, special purpose machines, specialised computer applications software and electro-chemical processes/systems.

Know-how for 104 different products and processes developed by ISRO and NRSA have been licensed to Indian industry so far.

(b) *ISRO Technological Consultancy Service*

Under this scheme, started in 1982, ISRO has been providing its expertise to

Indian industries and other R&D institutions by way of Consultancy Services in a wide range of technology and engineering disciplines. The areas of expertise include Chemical and Polymer Technology; Adhesives and Sealants Technology; Process Engineering; Pyrotechnic Systems; Computers; Design, Packaging, Production; Quality Control and Quality Assurance for Electronic Equipment; Composites Technology; Non-destructive Testing; Electro-optic Sensors and Systems: Electronic and Hydraulic Servo Control Systems; Structural Design, Analysis and Fabrication; Testing and Environmental Qualification; Precision Fabrication and Production Engineering; Design and Construction of Industrial Facilities; etc.

(c) *Industry's contribution to the space programme*

Much of the technology used in the space programme requires a high degree of sophistication and reliability. In addition, the low volume requirement combined with high standards of quality caused a reluctance for the industry to participate in the space programme initially, and ISRO had to rely mainly on in-house development. As ISRO's activities expanded in size and diversity and industrial capabilities and quality consciousness increased, ISRO is increasingly drawing upon the Indian industry to carry out various tasks for its space projects. Currently, a large number of industries are involved and the industrial contribution has become major part of the space programme. A list of the major contributors is given at the end of this chapter.

Manned Space Flight

Exactly four decades after independence, Indian space scientists are toying with the idea of sending a man into space. They are not, however, shooting for the moon, but planning to put an Indian astronaut into orbit around the earth. And this time they don't want to hitch a ride as Rakesh Sharma did, but are thinking of building an indigenous launcher and orbiter.

The manned spacecraft is one of the more exotic ideas being considered by ISRO scientists who are working out what shape the space programme should take in the 1990s. Scientists say that the plans for a manned space flight are only at a "preliminary stage", and a cautious ISRO Chairman Prof. U.R. Rao said, "While we would have the capability of launching a man into space by the 1990s, the real question is whether we can afford to do it and if so, how useful it would be for the space programme".

Currently, India's space programme is geared towards satellite building and launching. While satellites help improve telecommunications, broadcasting, national resources survey and meteorology, manned space flights have no immediate benefit except boosting national pride. Apart from that they could help in developing special alloys made only in space and useful for hi-tech industries.

Ever since they successfully launched SLV-3 that put the 35 kg Rohini satellite into orbit in 1980, scientists have been trying to upgrade their launching capability. ISRO is now planning to acquire one of the most crucial aspects of launch technology, namely, the cryogenic engine using liquid hydrogen and liquid oxygen. Scientists are working on the GSLV to launch the INSAT-2 class satellites into geosynchronous orbit by 1992.

Since most manned orbiters have a lower orbit of 300 km, the GSLV with an additional cluster of cryogenic engines would be technically capable of launching a manned spacecraft. But as one space scientist said, "Putting an orbiter that size is the least of the problems." What India needs to develop are sophisticated control and guidance mechanisms to manoevure the spacecraft and bring it back to land safely. Apart from thermal protection systems for the spacecraft, crucial life support systems like space suits, space foods and breathing apparatus need to be simultaneously developed.

Manned launches have further problems the spacecraft has to be made absolutely "fail safe". This means building redundant systems to take care of failures, thereby jacking up costs of a simple manned orbiter to Rs. 1,000 crores, the entire space budget for the last 10 years. But even if a manned spaceflight is not immediately feasible, ISRO is likely to take the first step towards it in the 1990s, the plan to develop recoverable booster rockets, thereby cutting costs drastically for every launch.

LIST OF SATELLITES AND LAUNCH VEHICLES USED INDIGENOUS AND FOREIGN

Satellite	Year	Launch
1. Aryabhata, indigenous scientific satellite	1975	Soviet launch vehicle
2. Bhaskara I, indigenous earth observation satellite	1979	Soviet launch vehicle
3. Rohini-1 (RS-1), indigenous technology satellite	1980	Indigenous SLV-3
4. APPLE, indigenous communication satellite	1981	European Ariane vehicle
5. Bhaskara II, indigenous earth observation satellite	1981	Soviet launch vehicle
6. Rohini (RS-D1), indigenous technology satellite	1981	Indigenous SLV-3

Satellite	Year	Launch
7. INSAT-1A, multipurpose satellite, built in USA to Indian specifications	1982	U.S. Delta vehicle
8. Rohini (RS-D2), indigenous technology satellite	1983	Indigenous SLV-3
9. INSAT-1B, multipurpose satellite, built in USA to Indian specifications	1983	U.S. Space Shuttle Challenger.
10. IRS-1A	1988	Soviet launch vehicle

INDUSTRY'S CONTRIBUTION TO THE SPACE PROGRAMME

ASLV	
Motor case hardware including nozzles for lower stages	Larsen & Toubro, Bombay Walchandnagar Industries, Walchandnagar, Anup Engineering, Ahmedabad
Fabrication of light alloy structures such as interstages and base shrouds and the heat shield	Space division of HAL, Bangalore
Forgings of 15CDV6 alloy steel	BHEL, Haridwar, Republic Forge, Hyderabad and Echjay Industries, Rajkot
Toolings for ASLV's strap-on booster	Polynics, Bangalore
PSLV	
2.8 m dia booster motor cases in maraging steel	Walchandnagar Industries, Larsen & Toubro
Handling rings for the first stage segments	Walchandnagar Industries
Light alloy structures including interstages and base shrouds	Hindustan Aeronautics Ltd, Bangalore.
Heat shields and liquid propellant tanks for the second stage	—do—
Core base shroud, heat shield and third stage adaptor structures	TANSI, Madras, NSE, Bombay and Southern Structurals, Madras
Maraging steel blooms	MIDHANI, Hyderabad
Rolling maraging steel into plates and forging into 2.8 m dia rings	Rourkela Steel Plant, Rourkela
Surface finishing of maraging steel plates to a very high accuracy	Leo Mercantile Corporation, Madras

Liquid engine and stage components	HAL, Bangalore, Vulcan-Laval Pune, NTTF, Bangalore Spundish Engineering, Bombay, CMTI, Bangalaore and Bharat Dynamics, Hyderabad.
Fabrication support for Al alloy base shrouds, boat-tails, fin assemblies, strap-on nose cone assemblies and maraging steel 'Band joint'	Godrej & Boyce, Bombay
Full scale dummy motor casting and dynamic mock-up hardware	—do—
Dynamic mock up including the water and propellant tank in Al alloy AFNOR-7020 and interstages and thrust frame using Al alloy AA-2-14	KCP, Madras
Tilting fixture for first stage segments	Mahindra Owen, Pune
Tilting fixture for the assembled motor	Southern Structurals, Madras

ROCKET PROPELLANTS

HTPB the advanced fuel-binder resin for the solid motors of PSLV & GSLV	NOCIL
Different grades of N_2O_4, the chosen oxidiser for the liquid stages of PSLV and the INSAT-II spacecraft propulsion system	Hindustan Organic Chemicals, (HOC), Rasayani and a small scale industry in Kerala
Unsymmetrical Dimethyl Hydrazine (UDMH) Monomethyl Hydrazine (MMH)	Andhra Sugars, Tanuku

LIQUID PROPULSION SYSTEMS

Nozzle thrust chambers and combustion chambers involving rolling and welding KC20WN (HS25) cobalt alloy sheets and precision machining	Anup Engineering, Ahmedabad, Vulcan-Laval, Pune
Precision machining of various components and the turbo-pumps of Vikas engines	MTAR, Hyderabad
Fabrication works related to turbo pump	NTTF, Bangalore & Veekay Industries, Bombay

Vikas engine components	Godrej & Boyce, Bombay Bharat Dynamics, Hyderabad, KELTRON Tool Room, Trivandrum and ART Industrial School, Tirunelveli
Vikas engine & stage parts	Kaveri Engineering, Trichy, and KCP, Madras
The structures for water tank thrust frame and interstage skirts fabricated	HAL (Space Division) Bangalore
The support for precision machining,	Larsen & Toubro, Bombay
Electronic Beam welding and pressure cycling tests for titanium alloy gas bottles	HAL, Bangalore and DRDL, Hyderabad
The POGO corrector assemblies	AURO Engineering, Pondicherry
Control system components of both PSLV & GSLV	KELTRON Central Tool Room, Trivandrum, Vinayaka CNC Centre, Bangalore, Machine Tool Aids & Reconditioning, Hyderabad, ITI, Bangalore and AURO Engineering, Pondicherry
Fourth stage elements of PSLV	Larsen & Toubro, Bombay Veekay Industries, Bombay, Orient Industrial Agencies, Bombay, McNally Bharat Engg., Pondicherry
Aluminium coating of 15CDV6 tanks for the PSLV first stage control systems	BHEL, Hyderabad
General fabrication support	SIDECO Tools, Quilon
Various engineering items	Echjay Industries, Gujarat, Delton Cables, New Delhi, NFC, Hyderabad and Ottoklin, Bombay
Indigenisation and new vendor development for PSLV titanium alloy billets	MIDHANI, Hyderabad
Titanium alloy forgings	Bharat Forge, Pune

SOUNDING ROCKETS

Metallic hardware for sounding rockets	Ramakrishna Engineering Works, Madras, Anup Engineering Works, Ahmedabad, and Alwar Engineering Works, Trivandrum
On-board telemetry, telecommand and communication packages for sounding rockets (items include timers, magnetic aspect sensors voltage regulators, VCOs, pre-amplifiers, PAM commutators, telecommand decoders, tone range receivers, etc.)	Space Electronics Division (SED) of BEL Bangalore

SPACECRAFT HARDWARE & FACILITIES FOR SATELLITE PROGRAMME

Light weight composite structures including aluminium honeycomb sandwich panels	Hindustan Aeronautics Ltd., Bangalore
Special mechanisms of INSAT-II and for their tooling, the facilities	HMT, Hyderabad, ECIL, Hyderabad, CMTI, Bangalore
Indigenous silicon solar cells for spacecraft, upgraded solar cells, Back Solar Reflector Cells (BSR)	BEL, Bangalore
Silicon single crystals for solar cells	Mettur Chemicals
Hybrid circuits trials	Western India Electronics
Screening support for electronic components	Electronic Regional Testing Laboratories (ERTL), Electronic Test and Desing Centre, Bangalore and ITI, Bangalore
Various ground accessories for mechanical integration and transportation of satellites	PSG Industrial Institute, National Aeronautical Laboratory, Consolidated Engineering and Saras Engineering, Bangalore
Cryogenic containers for satellite tests	Bharat Heavy Plates & Vessels
Liquid nitrogen	Indian Oxygen

Mcirowave Integrated Circuit (MIC) process qualification and subsequent fabrication and testing of 4W solid state power amplifiers operating in C-band and extend C-band frequencies for the INSAT-II communications payload	HAL, Hyderabad
High precision machined brackets for IRS payload	Paramount Machine Tools, Ahmedabad
Castings for corrugated horns	HAL, Bangalore
Design, fabrication and supply of multibus card frames, message switch enclosure	BM Design Centre, Ahmedabad
Fabrication of the main stainless steel chamber for 3m thermovac chamber	Anup Engineering, Ahmedabad
Copper fin tubes required for thermal shroud	Kamani Industries, Bombay
Transportable vacuum insulated liquid nitrogen tanker	Indian Oxygen, Calcutta
Gaseous nitrogen booster	LSM Maneklal, Ahmedabad
Small environmental test facilities including thermo-vacuum chambers, temperature and humidity chambers	Hind High Vacuum, Bangalore, and Heater Products, Bombay

LARGE SPACE SIMULATION CHAMBER PROJECT

Various ground accessories for mechanical integration and transportation of satellites	PSG Industrial Institute, National Aeronauticsl Laboratory, Consolidated Engineering and Saras Engineering, Bangalore
Cryogenic containers for satellite tests	Bharat Heavy Plates & Vessels
Liquid nitrogen	Indian Oxygen
Turnkey contract	BHPV, Vizag

GROUND STATIONS LAUNCH SERVICES TOWERS AND SPECIAL STRUCTURES

Development and supply of station processors	WIPRO, Bangalore

The servo system and the pulse code modulation systems for ground station fabrication	BEL, Bangalore
Fabrication of large antenna reflectors	Prabhakar Products, Madras
Antenna mounts fabrication	Andhra Pradesh Heavy Engineering and TANSI, Madras
Consoles and racks for the ground systems	ECIL, Hyderabad
Mobile service tower and associated systems for the launch range of PSLV	Triveni Structurals, Naini, Allahabad
Power supply, distribution and illumination systems	Siemens India Ltd, Madras
Air-conditioning, clean room requirements	Voltas
Steel material for the mobile service structure	The Steel Authority of India Ltd
Large stainless steel tanks and vessels needed for the launch services	Richards & Cruddas, Bombay
Cryogenic tankage	BHPV, Vizag
Establishing the ground facilities related to the Master Control Facility augmentation at Hassan to meet the needs of INSAT-II project	Electronics Corporation of India Ltd.
Ground antenna system for operation at S-band frequency	Prabhakar Products and Karthik Industries, Guindy, Madras

Special Bands chosen for the IRS-1 Cameras

Band	Spectral range	Remarks
1	0.45-0.52	Coastal environment studies, chlorophyll absorption region
2	0.52-0.59	Green vegetation, useful for discrimination of rocks and soil for their iron content.
3	0.62-0.68	Strong correlation with chlorophyll absorption in vegetation, discrimination of soil and geological boundaries.
4	0.77-0.86	Sensitive to green biomass, opaque to water resulting in high contrast with vegetation.

Summary Characteristics of the IRS-I Orbit

	Parameters
Repetition cycle	22 days (307 orbits)
Orbit height (km)	904
Inclination (deg)	99
Period (min)	103
Orbit decay (m/day)	6
Orbit correction cycle (days)	75
Swath (km)	
Low resolution camera	148
Medium resolution camera	2 × 74
Image overlap at the equator	9.4%

Specifications of IRS-1 Payloads

Item	Specifications	
	LISS-I	LISS-II
Focal length (mm)	162	324
FOV	9.4°	4.7° + 4.7°
IFOV (microrad)	80	40
No. of elements of CCD	2048	2048
Ground resolution (m)	73	36.5
Spectral range (μm)	0.45-0.86	0.45-0.86
No. of spectral bands	4	4
Swath (km)	148	74 × 2
Radiometric resolution	128	128
Data rate (mbps)	5.2	2 × 10.4

Mission Parameters of IRS-1

Local time of pass : 10 AM
Coverage cycle : 22 days
Swath : 148 km (LISS-I)
145 km (LISS-II)

Geometric resolution : 72.5 m (LISS-I)
36.25 m (LISS-II)
Spectral range : 0.45 - 0.86 μm in 4 bands
Radiometric level : 7 bits

Spacecraft Characteristics

Mass : 960 kg
Size : 1.6 × 1.56 × 1.1 m
Thermal control : Semi-active using heaters, tapes, MLI blankets, paints and OSR.
Pointing accuracies (3σ) : ±0.4° for pitch and role ±0.5° for yaw.
Jitter (3σ) : 1/10 pixel
Drift rate : 6.25×10^{-3} in 11 seconds
Solar array power : 709 watts (for normal incidence)
Battery : 2 × 40 AH
TTC frequency : S band and additional uplink in VHF
H/K bit rate : 256 bits/sec.
No. of data commands : 21
Data handling system : X band QPSK for LISS-II
S band BPSK for LISS-I

Advanced Materials

INDIA NOW runs neck and neck with technologically advanced countries in the development of high temperature superconductors with zero electrical resistance that can revolutionise the electronics and computer industry. The country can now produce metallic glass, a new class of material poised for revolutionising electrical industry and has made a major breakthrough in the design and development of optical fibres which have enormous promise in the field of communication, medicine and industry.

Superconductor Research

A significant and major achievement in superconductor research has been made by scientists at the Indian Institute of Technology, Madras, National Physical Laboratory, New Delhi, Bhabha Atomic Research Centre, Bombay; Tata Institute of Fundamental Research, Bombay and the Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam.

While in Japan, the United States and China, scientists have developed a new class of materials exhibiting superconductivity at 334 degree K (Kelvin is a unit of absolute temperature the coldest temperature conceivable), Indian scientists are very close in the race and have achieved the feat at a close of 300 degree K (27 degree Celsius).

The Madras Group of Scientists working in the IIT and the IGCAR have developed a variety of new materials, as many as 50, based on the rare earth-beriuim, copper, oxygen system and proved to be superconductors even at 95 degree Kelvin. Samples of National Physical Laboratory in New Delhi show superconductivity at 300 degree Kelvin. Many of the elements in the new alloys (dysporosium, holmium, erbium, thullium and ytterbium) are abundantly available in India.

The discovery, most scientists believe, can lead to incredible savings in energy. Trains that speed hundreds of kilometres per hour on a cushion of magnetism, practical electric cars, powerful, yet smaller computers and, particle accelerators, safe reactors operating on nuclear fusion rather than fission and a host of other rewards still undreamed of will be available.

Besides, it would be possible to make wires and these materials to reduce transmission losses in electricity transfer and also to produce huge magnets for industrial applications. Again, the superconducting materials could be employed in the manufacture of supercomputers.

Fibre Optics

Over 22 research institutions in the country are working on various aspects of materials and systems for optical communication such as drawing of low-loss optical fibres, splicing and connecting techniques, modulation and demodulation techniques, multiplexing and demultiplexing techniques and system studies.

The amount of information which can be transmitted by metal conductors is related to the wavelength of the electronic signal. Optical fibre can carry up to 10,000 times more information than a copper wire of the same diameter—allowing much smaller transmission channels, or alternatively, much higher transmission rates.

Scientists of the Central Glass and Ceramic Research Institute in Calcutta have developed optical communication fibres which are made from ultra-pure fused silicon tube having graded refractive index.

The Telecommunication Research Centre in Delhi has developed a terminal equipment for a 120-telephone channel system while the Indian Institute of Technology in New Delhi has a facility for testing fibres and engaged in perfecting already existing measurement techniques and trying to develop new methods to characterise fibres (pulse dispersion, attenuation refractive index profile measurement).

The Central Electronics Engineering Research Institute in Pilani has developed silicon avalanche diodes for detecting and decoding laser pulse at the receiving end while the Instruments Research and Development Establishment in Dehradun and the Central Scientific Instruments Organisation (CSIO) in Chandigarh have developed a variety of fibre optics components for various applications such as light guides of different lengths and apperture, aligned flexible fibre bundles used in sigmoidoscope, fibrescope and traffic signs; solid fused bundles or face plates.

The Defence Solid State Physics Laboratory in Delhi has succeeded in fabricating the gallium arsenide lasers while the CSIO is developing a machine for drawing plastic coated silica fibre. A more sophisticated facility at the Central Glass and Ceramic Research Institute in Calcutta has already produced experimental quantitites of 'graded-index' multimode fibres.

Research and Development and measurement techniques related to characterisation and evaluation of communication grade fibre are being done at Indian Institute of Technology (IIT), Delhi, and Central Scientific Instrument Organisation (CSIO), Chandigarh. These institutes are capable of performing well-identified and complementary tasks. Other IITs are also in the process of setting up similar facilities.

Research in the field of launching optical signals and detection of signals is going on in several institutions of the country. Work is also going on terminals circuitries for converting source detectors into different systems-required-transmitters/receivers and also repeater stations.

IIT, Kharagpur, has recently started an M.Tech. course covering technology of optical fibre communication system with its associated devices, materials and components to meet the manpower requirement. Courses on optical communication are also being given at some other universities.

In India, the first optical fibre communication system was set up in Pune connecting Shivaji Nagar and Cantonment Exchanges. Buried two metres underground, the glass fibre of 8 Mb/s capacity imported from Japan provided 120 telephone channel and has been functioning without any fault since 1979. A prototype of 40 Mb/s capacity, the second optical fibre communication system, developed by the Telecommunication Research Centre and the Indian Telephone Industry (ITI) will be commissioned by the end of this year. With installation of this system, the country would pass through demonstration stage and enter into commercial exploitation of this technology.

Metallurgy

Research in metallurgy in India is being carried out at Banaras Hindu University, Indian Institute of Science in Bangalore, the Defence Metallurgical Laboratory (DMRL) in Hyderabad, and Bhabha Atomic Research Centre (BARC) in Bombay. Special alloys and materials needed for aircraft and defence equipment are produced in a specially established factory in Hyderabad, known as MIDHANI.

The first ribbons of metallic glass rolled out of laboratory scale spin melt unit at BHU in 1978. Since then a few other laboratories started work on metallic glass. Two years ago eight research groups of different projects were funded by the Department of Science and Technology with the objective of developing a commercially viable technology for production types of metallic glass for applications in transformers cores. The Bharat Heavy Electricals Limited, India's largest manufacturer of electrical machineries, is involved in the research and development and hopes to commercially exploit this technology in the near future.

The nosecone of rockets made by the Indian space scientists use a technology for reinforced plastics with glass fibre. Fifteen research groups from universities and national laboratories under a project funded by DST have been carrying out for over nine years research and development of newer fibres and composites under this project. Technologies have been developed for producing glass carbon and organic fibres.

The notable achievements include development of E-glass and C-glass compositions; ceramic bushings to replace expensive platinum-rhodium for drawing glass fibres; process for producing aramid fibre similar to KEVLAR fibre, process for producing continuous carbon fibre production from special grade PAN fibre and a variety of processing techniques such as filament winding, pultrusion and products like impeller vanes, silos and slotted screen pipes.

The aluminium alloy conductor NML-PM 215, developed at the National Metallurgical Laboratory, Jamshedpur, has helped sizeable savings of copper. This alloy in the form of wire rod is being produced commercially at Bharat Aluminium Company in Korba. The Indian Cable Company in Jamshedpur is producing from the NML alloy wires meeting the specifications of the Indian Railways. A multistrand overhead conductors made from this alloy is being evaluated by the Ministry of Defence. At the Central Glass and Ceramic Research Institute in Calcutta, a facility has recently been set up for producing in pilot scale glass wires for optical communications.

Indian metallurgists have made significant contributions towards development of materials for the defence forces. Notable among them is the technology for making composite armour for battle tanks. The armour made of ceramic sandwiched steel composite armour called Kunchan armour is adjudged to be one of the best in the world and is to be used in the main battle tank being indigenously developed by the Defence Research and Development Organization. DMRL has also developed light weight ceramic armour against small arms fire and monoliothic steel armour for infantry combat vehicles. A major achievement of defence metallurgists is the development of armour piercing anti-tank projectile, an alloy material for use as penetrators. A Rs. 700 million factory to produce these projectiles is being set up in Tiruchirapalli in south India.

Scientists are also undertaking research on brake pads for various types in Air Force and civilian aircraft. DMRL has already developed the brake pad assembly of MIG-21 aircraft wheels comprising a bimetallic stator and a friction material rotor. The development was necessiated by an acute shortage of the Russian component in the Air Force inventories. The bi-metallic stator and the metallic-ceramic friction rotor are being produced at the Hindustan Aeronautics Ltd. (HAL), Koraput, and HAL, Hyderabad, respectively. HAL, Hyderabad, is also planning for a production of 10 lakhs break pad rotor assemblies per annum in the near future at a cost of Rs. 20 crores.

DMRL, the pride of Indian metallurgists, is in fact one of the best equipped laboratories in the world. The structural metallurgy laboratory has optical microscopes, X-ray diffractometers, an X-ray fluorescence spectrometer and a most advanced electron microprobe analyses with computer output. Among the latest acquisitions is the scanning Auger electron microprobe. The mechanical metallurgy laboratory is also comprehensively equipped: Instron, a hot torsin testing machine and a whole range of devices for fatigue and creep testing. A closed-loop servohydraulic universal testing machine has just been acquired. The nondestructive testing laboratory has ultrasonic flaw detectors, magnetic track detectors and instruments for gamma-ray and X-ray radiography.

Analysis of chemical composition of even microscopic amounts of sample materials can be made to a few parts per billion by instruments that include atomic absorption spectrometers inductively coupled plasma emission spectrometer, automatic recording spectroscope, Echelle D.C. and plasma spectrometer, a computer controlled oxygen and nitrogen analyser and analysers equipped with digital display for detecting carbon, sulphur and hydrogen. The power metallurgy laboratory is complete with a full range of presses and furnaces and full facilities for making dies. It can boast of a large-size organ atomiser, cold isostatic and hot isostatic presses suitable for development of production scale processes in powder technology. The hot isostatic press, which would be the pride of any powder metallurgy research laboratory anywhere, is the only such press in the country. It can produce directly from powder components almost in finished form, bond dissimilar materials, heat defects in metal casting or give a fresh lease to used up components like turbine blades that before had to be replaced and discarded. Among the other proud possessions of the gas turbine materials group are a 'burner rig' that can simulate temperature condition in a gas turbine and a plasma coating unit for protective coating of components against hot corrosion. Soon to be installed are two multi-kilowatt laser units for the most up-to-date development in processing metals.

There is a vigorously active group working on ceramic materials for applications in electronics and high temperature structures. DMRL has an automatic press, an extrusion press and high temperature furnaces to synthesise ceramic components for special applications.

Facilities exist for melting magnetic materials in bulk quantities, pressing and heat treatment of these materials in powerful magnetic fields and for evaluating the magnetic properties of the final products. There are also facilities for investment casting of turbine blades and other precision components. DMRL can now by directional solidification make fully columnar cast superalloy and even single crystal blades for turbo-jet engines. DMRL is now on the way to successfully developing the technology for investment-cast, directionally solidified, internally cooled turbine blades for a new aircraft planned for defence production in India.

DMRL is also working on the development of high temperature and high strength titanium alloys that could reduce the weight of jet engines, making them higher and more efficient and is all set to produce titanium metal in large scale batches using indigenous know-how in its demonstration plant.

Casting of titanium was once considered difficult if not impossible because of the molten metal's aggressive nature. DMRL scientists are trying to break this barrier by directly casting titanium alloys into required shapes. The latest forming techniques which are cost effective and energy saving are superplastic forming and diffusion bonding. The laboratory has identified titanium alloy that can be formed superplastically and have designed and built a special diffusion bonding set up.

The laboratory has developed the technology for liquid forging of various aluminium alloys, copper alloys and ferrous alloys.

The importance of special materials with high levels of purity in the successful implementation of our nuclear power programme was realised during the early days of the planning of our nuclear programme. Considering the long period of research and development in the laboratories followed by setting up of prototype plants that is needed before large-scale production units can be set up, work on many of the materials needed specially for nuclear programme was initiated in the early 1950s. This foresight has gone a long way in achieving self-sufficiency in the production of important special materials needed for the nuclear programme of the country.

Metallurgy of important special materials like tantalum, niobium, beryllium rare earths, aluminium oxide, magnesium oxide, zirconium oxide, rapidly solidified metals and oxides of uranium and thorium which are of importance in the nuclear programme and in the development of space, electronics and magneto hydro-dynamics technology has been extensively studied at Bhabha Atomic Research Centre (BARC), Trombay. These studies are backed with strong support to basic research in frontline areas like phase transformations, structure property correlations, diffusion, radiation, induced changes, fracture mechanics, failure analysis, stress, corrosion plating process and sintering mechanisms.

Excellent facilities exist in BARC for carrying out advanced research and development in many branches of metallurgy like extraction physical corrosion, electrometallurgy and ceramics. The programmes at BARC have established a sound base for production, processing, fabrication and application of many special and rare materials. This work has also served as the precursor of Nuclear Fuel Complex at Hyderabad. The Beryllium Plant at Vashi, New Bombay, and the Tin Demonstration Plant were set up near Raipur.

The Beryllium Plant at New Bombay has facilities for the production of beryllium blocks and for machining of beryllium into desired components. It also produces copper beryllium alloys. These materials and products are used in the nuclear and space programmes.

The Tin Demonstration Plant, built in collaboration with the Madhya Pradesh Government at the Urla Industrial Estate near Raipur, produces about 2 tons of tin metal per year from the cassiterite mineral deposit found in that area. The successful demonstration of the basic process developed at Trombay in the pilot plant will lead to setting up larger plants to meet all the tin requirements indigenously.

An aluminium base sacrificial anode (SUPERAL) for cathodic protection of ship's hull, developed at the National Metallurgical Laboratory (NML), Jamshedpur, is being used by industry. Stable integral colour anodising and electrolytic colouring of aluminium and its alloys have also been developed by NML. Aluminium alloy filler wire for welding electrodes has been developed. The know-how for reactive filter medium for grain refining of aluminium, developed by NML has been used by the industry.

"Pyroloy 1000", a heat resistant iron alloy which can replace other costly heat resistant materials in high temperature applications, has been developed at NML. Another cast iron alloy, which replaces imported materials in abrasion wear applications such as impeller blades in shot blasting machines, chute liners for sand slingers in foundries, etc, has been developed and christened as "NML-wearnot".

Nickle-free creep resistant austenitic steel developed at NML has been used to make automotive exhaust valves. Technology for production of different type of clad-metals like copper-aluminium stainless steel, mild steel, copper-mild steel, etc., has been developed at NML. Duplex, milk steel/tool bonded cutting tools leading to reduction in tool steel usage have been made by NML. Pilot level hydrostatic extruder has been used to extrude copper clad aluminium and complex profiles in copper and steel. Process for extraction of vanadium from wastes of alumina plants and from vanadiferrous iron ores developed by NML has been utilised by industry. A simplified and energy saving method for recovery of chromium from chromite ores has been developed by RRL, Bhubaneshwar. The laboratory has developed another process for depositing chromium in the form of brittle sheets from chromic acid containing sulphate ions.

A pilot plant for sintering manganese ore fines has been set up by RRL, Bhubaneshwar. Under a collaborative project with industry the laboratory has assisted in setting up a pilot plant for heat hardened agglomerates from sintered iron ore fines. Technology for production of electrolytic magnesium metals from different raw materials like magnesite, carnallite, dolomite and sea bitterns has been developed by NML.

The process has been developed for manufacturing several intricate components. The technology is being transferred to Bharat Earth Movers Limited for manufacturing chosen components used in the early moving equipment which are presently being imported. This will be the first such instance of a major manufacturing facility being set up for liquid forged components which will certainly generate awareness of this manufacturing technology in the country.

Fibres and Composites

In the field of fibres and composites, Indian scientists have developed newer fibres and composites having applications in industries such as aerospace, automobile, marine, chemicals, electrical and electronics. They have developed know-how for fabrication of aramid fibre, carbon fibres, optical fibres, and developed a number of resins and fibre reinforced plastic composite which may help in replacing metals because of their non-magnetic, corrosion resistant and energy efficient properties. These composites have high specific strength and specific modules and offer fibre-orientation as a new degree of freedom for the designer.

Work in India has been done in three phases—Phase I (1975-80), Phase II (1980-85) and Phase III (1985-90). In the first phase, development of fibres, which contribute mainly to the strength of a composite was taken up. The fibres selected for development were E glass fibre, polyacrylonitrile fibre, carbon fibre and aramid fibre. In addition, development of ceramic bushing for fiberising glass to replace the expensive platinum alloy bushing, fabrication of equipment like pultruder and user items like silos, was taken up. This resulted into development of E glass fibre, known as electrical grade fibre. A composition based on totally indigenous raw materials was developed by the Central Glass and Ceramic Research Institute (CGCRI) in Calcutta. The E glass produced conformed to international standards. Some inplant trials for productionisation were also conducted in cooperation with the industry.

A special grade of polyacrylonitrile fibre is the precursor for carbon fibre required for reinforcement. Copolymers and their fibres were prepared and tested in the laboratory and other studies were carried out by the Central Leather Research Institute (CLRI), Madras.

In the field of carbon fibres, the National Physical Laboratory (NPL) in New Delhi has carried out detailed laboratory studies on stabilisation by oxidation and two state carbonisation of imported special grade acrylic fibre. Special parameters of the precursor fibre, which directly influence the formation of good quality carbon fibre were studied in the laboratory. Recently the laboratory has started semi-commercial production of these fibres.

The established industrial practice of fiberising glass is through platinum alloy bushings. Laboratory studies on the development of an alumina bushing for fiberising glass at IIT, Kanpur, were successfully conducted. A glass fibre manufacturing industry is in the process of trying out the developed process as per industrial practices.

A number of products based on fibre reinforced plastics (FRP) products like silos, designed and fabricated bv Vikram Sarabhai Space Centre (VSSC) which were tried by the Foodgrain Storage Authority (Warehousing Corporation) at Hapur and impeller vanes, also designed and fabricated by VSSC, were found acceptable.

In the second phase—during 1980-85—efforts of Indian laboratories were concentrated on development of matrix resin systems and related ancillary chemicals. The methodology and philosophy of work of Phase I was continued. This phase was extended beyond 1985 to allow completion of residual work on some systems and scale-up activity of the systems.

During 1980-85, reactive polyamide curing agent for epoxy resins which imparts flexibility and consequent high impact strength to the cured resin were developed by VSSC on a 30 kg batch level. The product was evaluated by the National Aeronautical Laboratory (NAL). The process details, along with specifications, were intimated to NRDC for transfer of technology to industry.

Polyamide (condensation type) resin based on pyromellitic dianhydride is recommended for high temperature resistant electrical insulation coating/film. The resin system, developed by VSSC, was tested by an industry as an insulation coating of wire. The process details along with specification were intimated to NRDC for transfer of technology to industry.

Furfurdehyde is indigenously manufactured from renewable source materials. The alkali resistance and dielectric strength of phenol-furfuradehyde are superior to those of general purpose phenol-formaldehyde resin. One such resin system was developed by Sardar Patel

University (SPU), Vallabh Vidyanagar, and large scale preparation up to 10 kg batch level was studied by VSSC. The resin was evaluated by NAL as matrix resin for glass fibre composites and its superior alkali resistance checked with carbon fibre composites. Its superiority over phenolic resin as preforming resin for carbon-carbon composites for producing composites of higher density and flexural strength was established by NPL. Its superiority for making into standard grades of moulding powder and mouldability into standard mechanical and electrical goods was established by industry. The resin system has been put up for transfer to industry by the Department of Science and Technology.

Pitch impregnating resin conforming to international standards was developed by NPL and evaluated by industry. NAL evaluated carbon-carbon composites made by NPL using this pitch. The process is proposed for further study on a larger scale in the first stage by NPL and finally by RRL, Hyderabad.

Vinyl ester resin was developed by Indian Institute of Technology (IIT), Delhi, on laboratory scale initially for facilitating low temperature polymerisation of bismaleimide. Its development as matrix resin for glass fibre composites was followed up after testing by NAL and then scaled up by VSSR on a 30 kg batch level. It has been evaluated by industry for suitability, for fabrication of containers, for chemical industry.

Two grades of Bisitaconimide resins which are high temperature resistant matrix resins, high performance grade and low cost grade have been developed by VSSC and evaluated by NAL. Large scale preparation of the high performance grade was also studied by VSSC and the process parameters were finalised. Scale up of the low cost grade is in progress. A high performance grade of Bismalemide resins with high char yield value was developed by IIT, Delhi, and tested by NAL. Scale up of this system is in progress.

Enhancement of mechanical and thermal properties by reinforcing polypropylene leads to higher performance and value added products. Polypropylene reinforced with either mica fines (a waste byproduct in the country) or talc or calcium carbonate were developed by Indian Petro-Chemicals Ltd. (IPCL), Vadodara. These reinforced materials were found to have good processing characteristics and process reproducibility. The reinforced compounds were evaluated by NAL, Bangalore, and IIT, Bombay. Mouldability of the filled systems for products like moulded luggage, two-wheeler engine, housing for fan regulator, acid battery covers and fan blade assembly was checked and the standard of mouldability was found to be good. Fan abide assemblies moulded from reinforced polypropylene are under evaluation for performance by the industry.

Boron trifluoride-monoethylamine complex curing agent which is a special purpose delayed action type agent for epoxy resins is capable of producing high crosslink density and high order of electrical properties. It was developed by VSSC and evaluated by NAL.

HET acid based polyester resin which is a transparent flame retardant grade polyester matrix resin for glass fibre composites was developed by Sri Ram Research Institute, Delhi, and evaluated by NAL. Reproducibility was checked on a laboratory scale and specification was drawn up. The know-how is available to entrepreneurs for scale up and transfer.

Y-methacryloxypropyltrimethoxy silance which is an effective coupling agent used extensively in good quality glass fibre reinforced polyester composites was developed by IIT, Delhi. The know-how is available for scale-up and transfer.

The current trend is not to wait for development of an asoteric new polymer to meet specific property and process requirements but to try to acquire them by blending/alloying polymers for desired property/process advantages. One such alloy of commercial polymers based on polyethylene terephthalate (PET) and polymethyl methacrylate (PMMA) was developed by National Chemical Laboratory (NCL), Pune, to give the process advantage of using of mould at low temperature. Melt-mixing of the constituents polymers was done by NCL with the twin screw extruder. The alloy was injection moulded with facilities available in industry and was tested. Dialogue with industry is on to identify likely commercial products for development from the developed alloy and their subsequent evaluation.

Cashew nut shell liquid (CNSL) is a large, low cost, indigenous vegetable source of phenolic compound and can be exploited to make many value added products. One such product, panels for housing for rural sector is an attractive application. The resin formulation based on CNSL, developed by NCL, Pune, was found to be a suitable matrix resin for bamboo mat and some indigenous low cost particulate filters. A design of a house made up of such panels for the rural sector is being worked out in consultation with architects and structural engineers to scale up the production of the resin and fabrication of the panels.

Aramid fibre (Kevlar type) of high strength, high modulus and low weight is used to produce composites that are known to fail in the ductile mode only. It finds large scale application as a superior reinforcing organic fibre in aerospace and aircraft components, personnel armour, V-belts and for reinforcement of rubber tyres of four-wheelers. Intermediate batch level study of the process of preparation of the polymer and spinning fibre from it has been in progress at NAL with equipment designed, fabricated, installed and commissioned by NAL. The process parameters are under optimisation after which the process will be ready for scale up by industry.

A pultrusion machine for fabrication of glass fibre reinforced polyester composite hollow tubes and sections was designed by VSSC. Some components were made in-house while others have been ordered from industry.

Ten products based on indigenously available glass fibres and polyester/epoxy resins were identified, designed, fabricated and tested by Poona University. All of them including paraboloid dish for solar concentrator and gasholder for gobar gas plant, are undergoing field trials.

NAL studied crack propagation by acoustic emission monitoring of an IOSIPESCU type of composite test specimen subjected to shear stress.

Regional test centres for testing resins, fibre and composites to facilitate evaluation of raw materials, composites and products by the FRP small-scale industry have been set up at IIT, Bombay, and IIT, Madras. The centres, which were funded in 1982, have now established all facilities for physical and mechanical tests. Both the centres have been testing raw materials and composites for the industry. Brochures and compendia of tests prepared by both centres for the information of industry are available. Get togethers, seminars and workshops for industry are being arranged annually by both centres to bring an awareness of the test facilities and the importance of various tests in ensuring quality control. To encourage introduction of regular testing of products in industry, particularly at the small-scale level, testing was done at both the centres free of cost for a limited period. A scheme is now being drawn up to make both the centres self-supporting and to continue to give assistance in quality control to the FRP industry.

Carbon-carbon composites (C-C composites) have shown considerable promise for use as bioimplant materials and are being investigated extensively. A plan for systematic in-vitro and in-vivo evaluation of C-C composites was drawn up by the Sree Chit, a Tirunal Institute for Medical Science and Technology, Trivandrum (SCTIMST). Some C-C composites required for this study have been made and supplied by VSSC and NPL with funds sanctioned by DST. Studies carried out by SCTIMST have shown the material to be of acceptable quality in in-vitro tests and results so far obtained in in-vivo tests point to the trend in the same direction. Design of test equipment for long-term mechanical tests has been completed and fabrication is in progress.

Studies to use of composite materials in rehabilitation aids kits being jointly carried out at SDM Hospital, Jaipur, and IIT, Bombay. The first product chosen for development was a device based on floor reaction orthosis to replace metal calipers for polio-affected patients. Designed and fabricated by IIT, Bombay, and evaluated and field tested by SDM Hospital, Jaipur, the FRP aid made of carbon fibre cloth and epoxy resin has proved to be an instant success. This new device weighs about one-fourth the weight of steel calipers and is quality rigid. It is also comfortable to wear and does not require special shoes. There has been a total enthusiastic and wide acceptance by the patients (so far about seventy). A few minor improvements to increase the wear resistance of the foot portion of the device are being studied. Rehabilitation aids for above-the-knee and below-the-knee amputees are also under development with similar composite materials.

Desirability of development of such resin systems with high impact strength arose out of the knowledge gained from the study tour of project investigators during Phase II. Such resin systems find extensive applications in plotting, encapsulation and similar fields. As VSSC had already some expertise in the field related to toughening materials, a project for the development of the identified epoxy resin systems was initiated and funded at VSSC.

Development of polymers and FRP composites for specific products applications is being taken up now. It has been realised that if the development of these materials is to be meaningful, it has to be related to specific products. This orientation can be achieved only if the demands of several sectors of industry are scanned and reviewed. Further the development of a composite based product for an industry cannot lead to realistic achievement unless a total involvement of the concerned industry units is brought about during the planning of the project. Their commitment includes providing the needed direction to the R&D to meet the desired goal and giving direct or indirect financial support wherever needed. Involvement of industry right from the inception of a project is expected to ensure:

- meaningful R&D activity leading to products of direct and immediate interest to the user industry.
- participation and contribution of user and manufacturing/processing industries right from the project initiation stage to ensure correct direction of projects activity and timely inputs for the evaluation of the decided stages of development.
- preparation of an efficient and complete technology package for smooth transfer of know-how to industry and
- reduction of time lag in utilising the results of the R&D activity.

Defence and Aeronautics

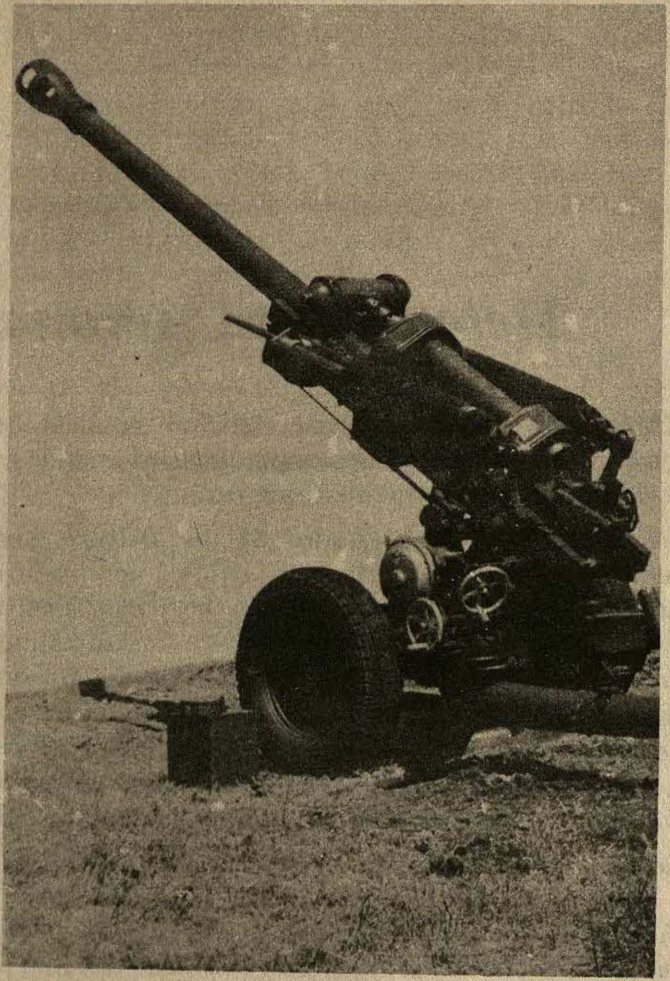
INDIA HAS had to develop special skills in national defence and aeronautics in view of growing international tension and the induction of sophisticated weaponry into neighbouring countries.

As many as forty-two laboratories of the Defence Research and Development Organisation (DRDO) have achieved significant successes in indigenisation of technology, particularly in the field of small arms, guns, ammunition. instruments, ballistics and modern explosives and developed over hunderds of sophisticated equipment to meet the growing needs of India's defence. The laboratories, in the national quest for a self-reliant defence posture, endeavour to provide the research, design and development base for meeting the needs of the armed forces—ranging from aircraft, missiles, tropedoes, radars and tanks to frozen food and nuclear medicine.

A sizeable measure of self-sufficiency has been achieved in the areas of small arms and ammunition. The Ishapore rifle, the mountain gun and the Indian field gun, mark to which DRDO made significant contributions, are now in use. A self-propelled artillary gun has also gone into production. Various types of proximity fuses and liquid fuel rocket engine have also been developed.

One of the prestigious projects of defence R&D related to the design and development of the Main Battle Tank (MBT) christened 'Arjun', the prototype of which is already developed. It has a powerful 120 mm rifled gun capable of firing 'APFSDS' rounds of exceptional lethality. The tank has a most advanced gun control system and associated opto-electronics with the capability to fire on the move or a moving target. Test bed experiments, conducted at the Combat Vehicles Research and Development Establishment, Avadi, Madras, shown an overall efficiency of around 90% which is quite comparable to some of the best design developed elsewhere.

Besides, important contributions of defence scientists in MBT consist of developing a high energy propellant and semi-combustible cartridge cases



An Indian Field Gun.

for use in its ammunition. The semi-combustible cartridge cases save the use of imported metal and alloys and help in logistics also. High energy propellant gives MBT gun ammunition a greater range and higher penetration into the armour. A protective liner composition has been developed which surrounds the propellant in the cartridge case and increase the life of the gun barrel which otherwise suffers from erosion.

Breaching of mine fields is one of the important requirements of the Army, to facilitate advancement of troops in the battle field. A device, designated, 'Charge line mine cleaning' to clear a safe line has been developed which has proved an important equipment for the infantry.

The first BEML-TERA heavy duty truck manufactured by the public sector Bharat Earth Movers Limited. The heavy duty truck is a high-technology import substitution equipment being manufactured in India for the first time in collaboration with M/s Omnipol of Czechoslovakia. The 355 HP truck is designed to meet the off and on highway transportation needs of the defence and civilian sectors. It will also be used to transport the Bofors guns, recently acquired by the Army.

Development of a process for the manufacture of a high explosive 'B-HMX' and design, fabrication and setting up a plant is another important achievement in the field of high explosive. In the field of armoured and specialist vehicles, the important achievements include Shaktiman, amphibian vehicle, recovery vehicles and powered axle trailer. Tasks of mounting 40 mm gun on Shaktiman, 106 mm RCL gun, 7.62 mm self-loading rifle, medium machine gun (MMG) and 0.5 HMG on Jonga vehicles, and Bofors guns on BEML—TERA heavy duty truck have also been successfully completed.

Two major missile system have been developed for the Army. The first is the anti-tank missile which is completely indigenous in design and has established the specified level of performance. The second is the medium range surface-to-air missile which has undergone flight trials successfully.

MBT—India's Main Battle Tank—Arjun.

Another achievement is the development of rapidfire multi-barrel rocket system which neutralize the enemy position very quickly. An interim test range is now being set up in the country for testing rockets, missiles and targets.

Indigenous technology for making large size solid propellant grains has also been established. Consequently a number of propellants for surface-to-air, surface-to-surface, and air-to-surface missiles has been developed to meet the specific requirements.

Food

The technology that keeps food in hygienic condition over a long period of time in space travel and provides nutritious food to millions of jawans working under tough climatic conditions has been developed by the Indian scientists. Such food has already been consumed by members of the eight Antarctic expeditions certifying its quality, nutritive value and capacity to endure longer period of preservation.

The Defence Food Laboratory and the Central Food and Technological Research Institute of CSIR, Mysore, have developed various products, processes, preservatives and flexible packaging materials transforming the all too difficult national cuisine into packaged and processed food nutritious and appetising.

The institutes have to their credit the development of a number of products such as preserved chapatis, compressed ready-to-eat bars, preserved bread, canned Indian dishes, quick cooking foods, survival ration and frozen dried products. Side by side with the development of products, they had also modified existing test methods and developed new analytical techniques to monitor the quality of food products.

Chapati is a common Indian food and staple ration item of the armed forces. Its preservation is an operational requirement particularly in areas where facilities for cooking are limited or non-existant. Studies indicated that chapatis could be preserved on a short term basis for a period of 10-14 days by incorporating sorbic acid and then packaging in polythene packets. Heating the chapatis by dipping the polythene pouch in hot water improved their acceptability. The method is simple and can be easily adopted in any army kitchen without any additional facilities. The chapatis packaged in paper foil/laminate pouches could be preserved for six months. Incorporation of fat, milk powder and oleresins of cumin seeds and cardamom improved the texture, flavour and acceptability of preserved chapatis.

For India's first cosmonaut Sqn. Ldr. Rakesh Sharma's special food and packaging methods were developed as weightlessness in space makes simple operation difficult because normal food stuffs start floating inside the space ship. Bread meant for cosmonauts looks more like a set of chocolates. The explanation for this is that if one cut bread with a knife bread crumbs will spread throughout the station, turning it into a disaster area.

To prevent bread from becoming stale too quickly, it is packed in two cellophane wrappers and special double sterilisation prevents bread from growing fungi. Initially, three varieties of bread were made for cosmonauts but now there are more than six such varieties. Meat products are tinned. Some of the foodstuffs in the form of bars and covered with an edible film. According to this preservation method, the first and second courses and juices are prepared and frozen quickly and then are dried in vaccum. Not more than two or three per cent of the water is left, food can be stored for a long period of time and above all they almost fully preserve their taste.

At least 70 types of foodstuffs are included in on board stocks. The institutes have designed many different fixing rods as well as special knives for opening tins and tubes. One of the devices called the 'bell' prevents splashing about of the contents when the pressure in the tube after heating is higher then the pressure of the surrounding atmosphere. The electric cooker used abroad of the last Salyuts make it possible not only to heat up the items but also to freshen bread.

Several compressed ready-to-eat formulations based on processed cereals, pulses, vegetables or mutton mince had been developed. These products are compact and withstand transportation better when packed in flexible pouches. The bars have a shelf life of more than one year at ambient temperature and under diverse field conditions. Depending at the rate of 4 or 5 per man per day, they are useful as an individual ration for subsistence during emergency or as part of packed rations.

A fungistatic wrapper has been developed for keeping bread for a period of 7-10 days. Even fresh bread when wrapped in a fungistatic paper with an overwrap of paper polythene laminate remained in acceptable condition for a period of 7-10 days. The Defence Food Research Laboratory (DFRL) regularly supplies the lingistatic paper to Navy who get their requirements of preserved bread directly from bakeries.

In India, canned products constitute the largest volume of processed foods, most of them catering to the requirements of the Defence Forces. However, only a few canned products cater to the Indian palate. Hence, processing conditions were standardised for canning a number of items of the traditional Indian dietary. Canned pulav (vegetarian and non-vegetarian), kofta, curries, peas, panner, potato, peas curies, mutton keema, luncheon meat from mutton, puris, parotas and buddings like kheer, suji halwa and upma have been developed.

The traditional Indian diet comprises three important components, viz., rice, pulses and vegetables and, to a lesser extent, meat. As they require long cooking time particularly at high altitudes, these foods as such cannot find place in the ration packs. The shelf life is also limited in case of vegetables and meat. Thereafter precooked dehydrated products, having short reconstitution time and longer storage life have been developed. These products are used either as such after rehydration or for the development of convenience foods like pulav (vegetarian and nonvegetarian) khichidi, omelette mix, avail mix, curry mixes, sambar mixer, cutlet mixer (vegetarian and non-vegetarian) soup mixes, hamburger mixes, stew mixes and various types of sauces. Novel techniques like use of enzymes, high temperature short time pneumatic drying are used for developing these products which reconstitute either instantly or within a short time. Conventional hot air dehydration of 60-70°C, requires considerable time to bring the moisture level of the production to 5-6 per cent. This adversely affects the texture, flavour and reconstitution of the product. The drying time can be considerably reduced by adopting the 'HTST' method. With this technique the products are superior in texture and flavour and have low reconstitution time and very high acceptability.

In spite of the advantages of conventionally rehydrated foods, acceptability of several items has suffered because of a few disadvantages like poorer texture, and rather prolonged reconstitution time and difficulty in preparing products having particulate pieces. Freeze drying technique which had been earlier confined to expensive pharmaceutical products has been successfully utilised in freeze drying a number of products like mutton chunks, curried mutton, vegetables, fruits, kheer, mushroom and pulav. Freeze juice powders, have a very high rate of acceptability and convenience in use.

This technique aims at stablising dried foods at intermediate moisture (IM) level (25-50%) and to keep water activity at safe levels to prevent microbial spoilage. IM foods have the advantage of having sufficient moisture to be eaten without further preparation and will also keep long without refrigeration or thermal processing. The products developed include carrot, apple, pineapple, guava and banana.

One of the major problems for which a satisfactory solution is yet to be found in the provisioning of survival foods which would allow a person to survive for a period of 5-7 days with minimal water requirement and minimal losses of physical and mental faculty and which are suitable for use by soldiers, sailors and airmen isolated during action. A soft candy bar (fudge type) with cocoa flavour has been developed taking into consideration the physiological requirements and other limiting factors under survival conditions. The soft candy bar packed in flexi pack has a satisfactory storage life under all conditions of service use.

In the field of packing system, the existing ISI specifications are not comprehensive and do not cover all packaging materials. Hence the available materials were surveyed for possible use with processed foods. It has been possible to identify laminates for use with (1) dehydrated foods which are highly sensitive to oxygen and moisture like freeze dried meat (2) pickle and other all containing foods (3) dehydrated items like peas, preserved chapatis, etc., and (4) in pack processed ready-to-eat foods. Light weight packaging systems using flexible materials and cartons have been developed for composite pack rations. By this the weight of the packaging could be reduced to 75 per cent and the cost be brought down considerably as compared to the previous systems of packaging in tin containers. A simple technique has been developed to enhance the shelf life of perishables like fruits and vegetables. The method can be conveniently utilised for transporting fresh fruits and vegetables in forward areas and also on board Indian Navy.

Conventional jute bags used for wheat based milled products like atta, maida and suji do not provide adequate protection against moisture and insect ingress especially under humid tropical field conditions. A single packaging system, viz., bags made of 'HDPE' woven fabric coated with 'LDPE' followed by 'A' for 'B' twill jute bag was found suitable for adoption for various types of rations.

Record processing of various foodstuffs of Indian dietary was undertaken as soon as polypropylene film and its laminates were indigenously available. Because of the thermal changes occurring during processing, an overall packaging system and a modified processing technique was developed to suit this material. Items developed by this method include mutton and vegetable biryani, mutton, kofta, curry, suji halwa, kheer and baked beans in tomato sauce.

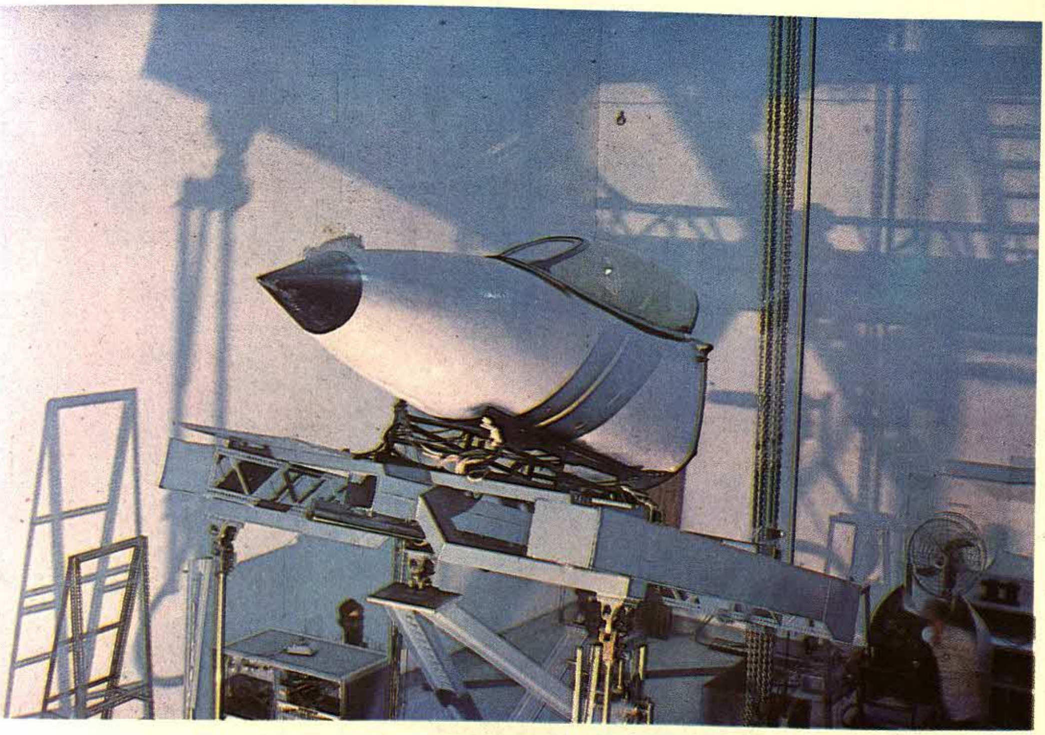
Flavour of processed foods often deteriorates long before their nutritive and other functional properties are lost and thus is one of the limiting factors in the shelf life of the processed foods. New aproaches in this field include use of flavour precursors, flavour enzymes and flavour potentiators for enhancing the shelf life.

In the area de-emulsification of butter which is a serious problem during summer months, the laboratory studies have established that butter with 10% milk solids incorporated in it, remained in good and acceptable conditions under all types of climatic conditions prevailing in the country. The process can be easily adopted by any commercial manufacturer of butter. The treatment on a commercial scale had no adverse effect on the microbiological and organoleptic acceptability.

Flavour degradation and discolouration are the two major causes of spoilage in dehydrated fruits and vegetables. In dehydrated carrots, the factor determining the shelf life of the product has been found to be the degradation of carotenoid which results in any hay and voilet type of odours during storage. The various volatile and non-volatile products of stored carrots have been indentified and the role of lipids, antioxidants, salt and water activity on the rate of carotenoid degradation has been established. Pretreatment for carrot have been standardised to improve carotenoid retention and texture. In case of onions the major cause of lower acceptability is the low level of pungency in dehydrated products. Effect of temperature, varieties and additives on the alliaceous activity which determine the pungency have been investigated.

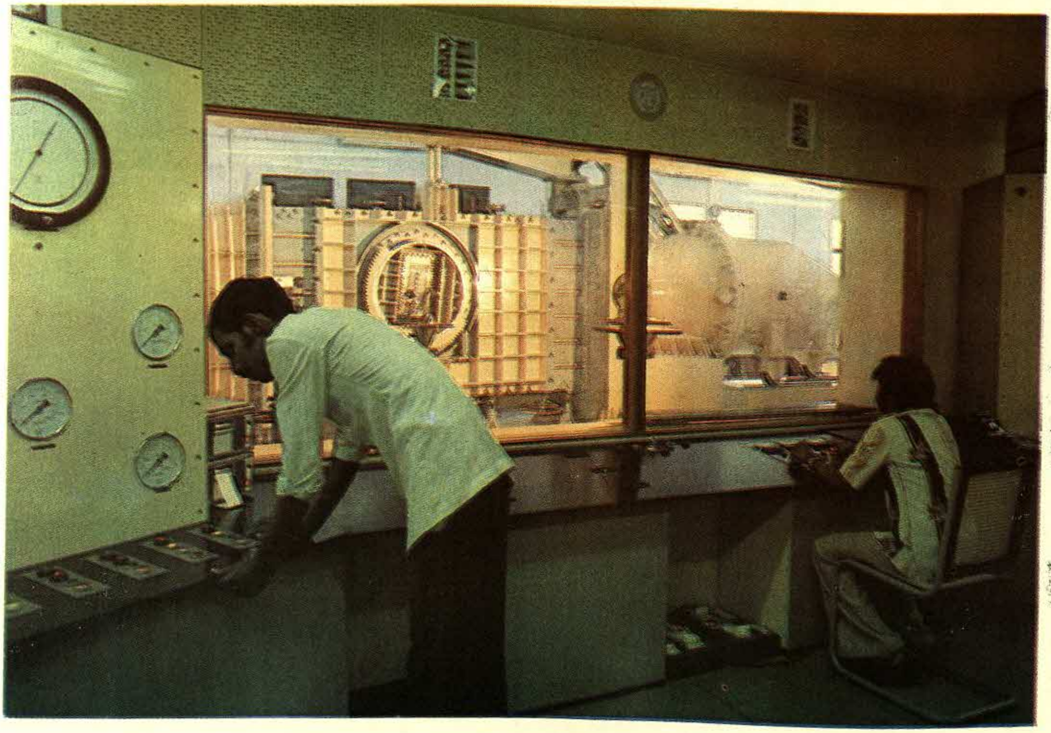
Aeronautics

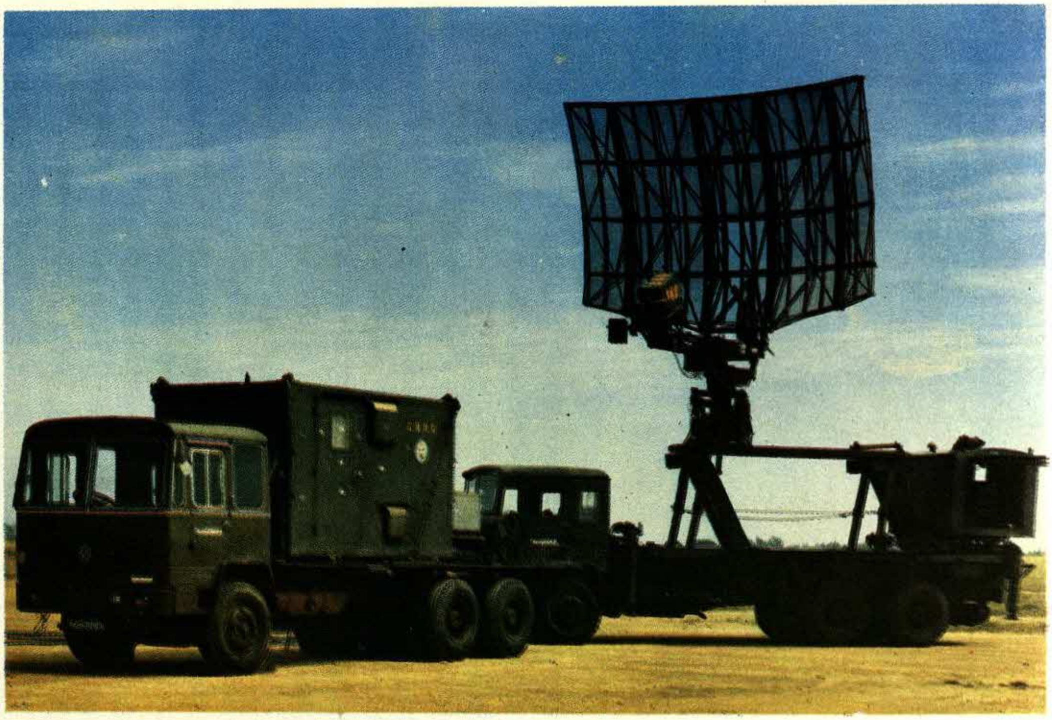
In the area of aeronautics, the impetus has come from the defence project of



Aircraft Testing Facility at NAL, Bangalore

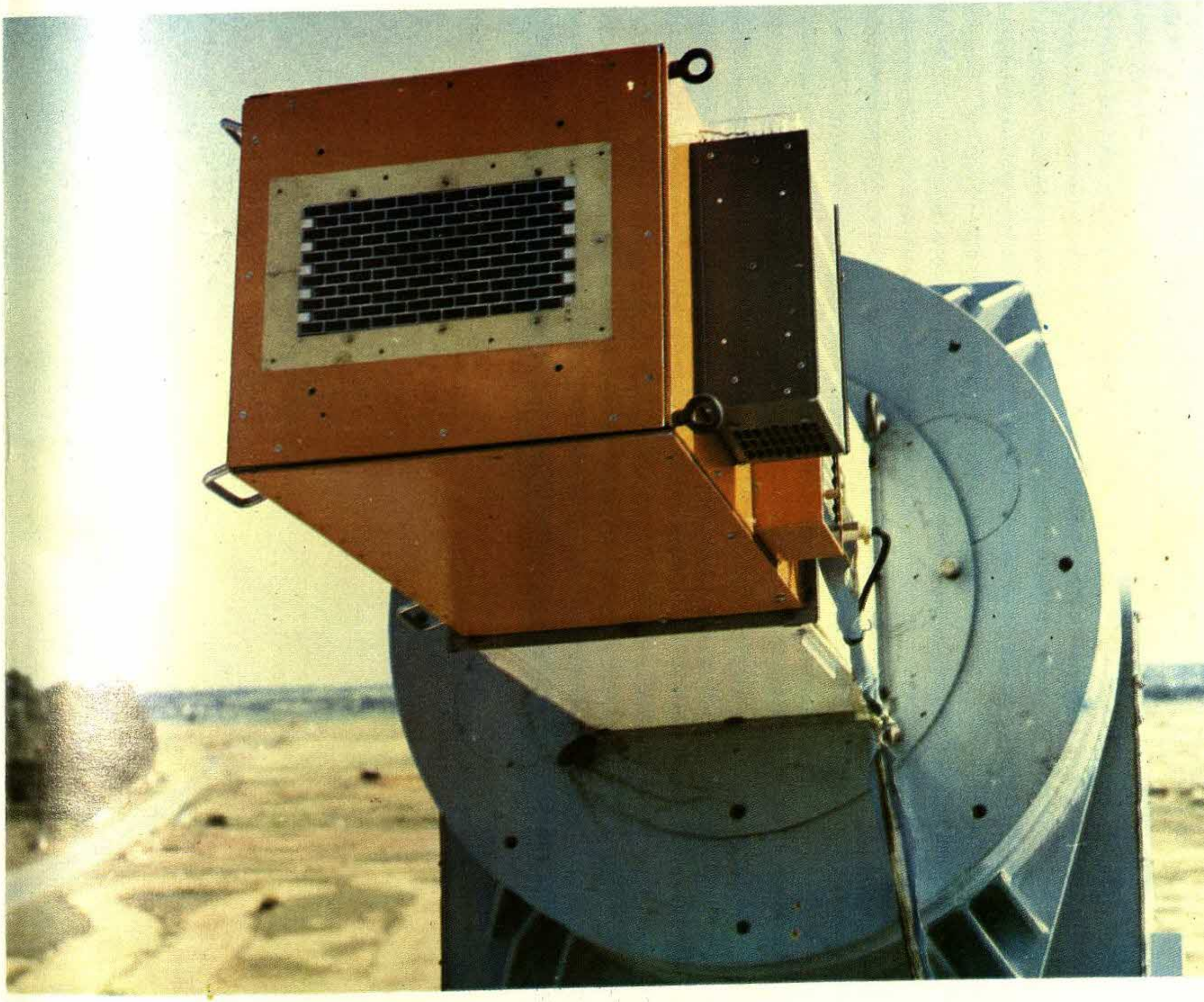
Turbo Testing



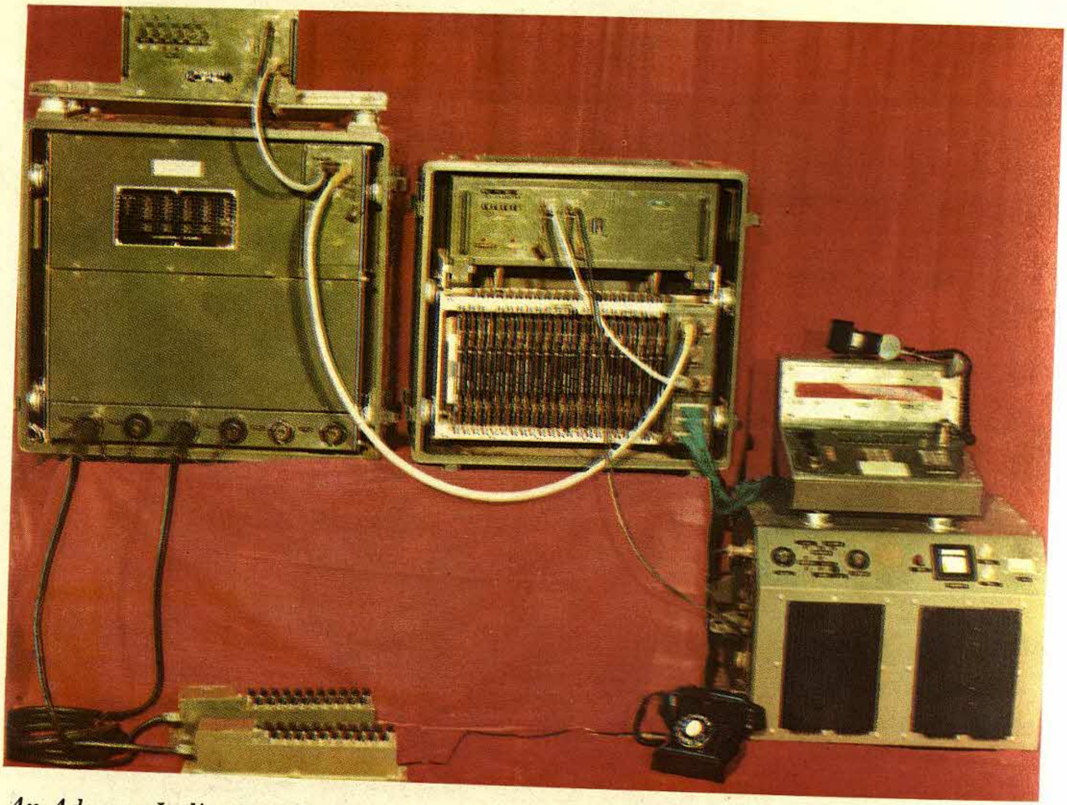


A View of Indigenous Radar

Secrecy Systems

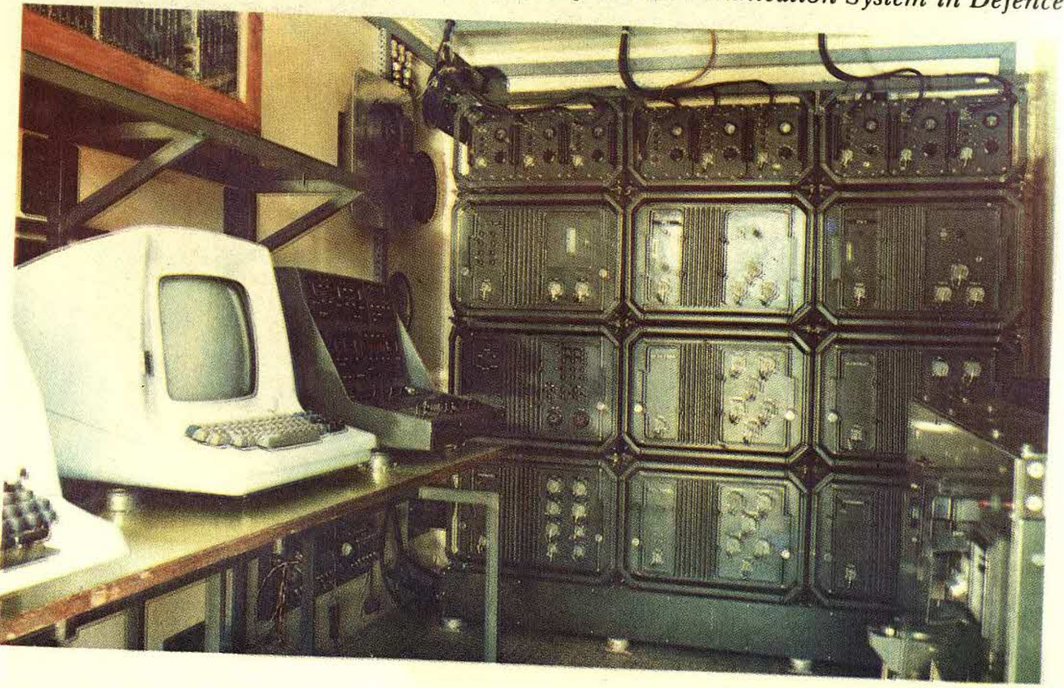


Antenna of Radar



An Advance Indigenous Communication System

A View of Computer Communication System in Defence



light combat aircraft (LGA) being executed by the autonomous Aeronautics Development Agency in Bangalore.

The Indian aircraft industry was started with Government of India by taking over during the Second World War what was then a joint venture between the then Mysore Government and Walchand Industries to develop an Indian aircraft industry. This was used as a repair base for the South East Asia Command during the World War II; after the war, the factory was busy converting war surplus DC 3 aircraft to civil versions which saw launching of commercial aviation companies. These were eventually taken over by the government to create what is now the Indian Airlines.

First efforts to develop aircraft indigenously were made by Dr. V.M. Ghatage who was the first Head of the Aeronautics Department at the Indian Institute of Science in Bangalore. The first aircraft developed by him, after being appointed as Chief Designer of the Hindustan Aeronautics Ltd. (HAL), was the HT 2 trainer and this was followed by a number of light aircraft which were productionised.

The first military strike aircraft developed in the country was HF 24 (Marut). The design of the aircraft was conceived by the German Designer, Dr. Kurt Tank and it was developed by the Indian scientists. This for the first time India tried to come to grips with the design and development of fighter aircraft. In its aerodynamic design concepts the aircraft was comparable to those from the developed world but unfortunately it could not achieve its design performance as the engine around which it was designed was not available.

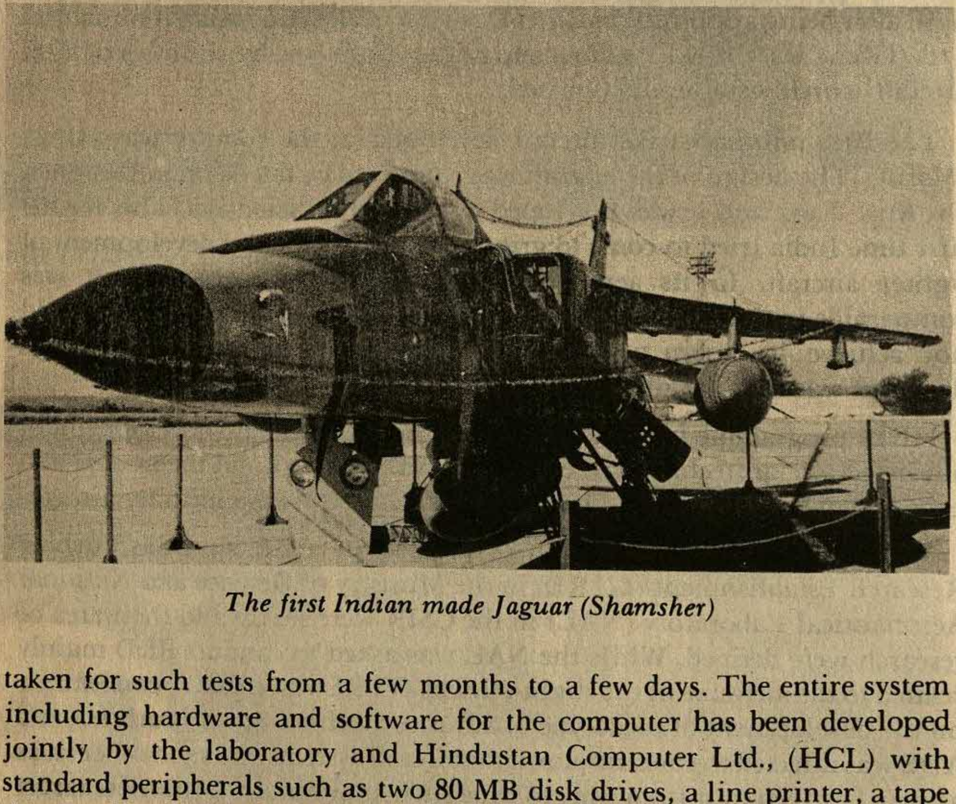
HF 24 programme taught India that without design and development of advanced aircraft technology, extensive R&D facilities and theoretical and experimental data, it would not be possible to develop a military aircraft.

The Aeronautical Development Establishment (ADE), and Gas Turbine Research Establishment (GTRE) in the Ministry of Defence and National Aeronautical Laboratory (NAL) in the CSIR were set up and their area of research were defined. While the NAL was asked to conduct R&D mainly related to the airframe of the flight vehicle, GTRE was asked to concentrate on the development of prototype of advanced technology gas turbines and ADE was directed to concentrate on the aircraft systems and such other tasks as may be given to it from time to time such as simulators, pilotless target aircraft, remotely piloted vehicles.

The National Aeronautical Laboratory over the years has evolved itself into a well developed applied research laboratory in its area of responsibility. The 1.2 m×1.2 m trisonic wind tunnel became the focal point for its aerodynamic research activities. It has obtained good capability in vehicle aerodynamics, computational fluid dynamics, computer-aided design and structural analysis, analytical techniques for application of composite materials to structures, etc.

The Flight Mechanics and Control Group of the Systems Engineering Division (SED) of NAL has made substantial progress in designing fly-by-wire systems, flap controls for fighter planes, electronic systems, including microcomputers for aircraft, power electronics and telecommand are other major areas of R&D work at the SED.

The Structure Division of the NAL has recently commissioned a new computer assisted vibration test and analysis (CAVI-TAS) to conduct vibration test on aero-speace structures. The new system cuts down the time taken for such tests from a few months to a few days. The entire system including hardware and software for the computer has been developed jointly by the laboratory and Hindustan Computer Ltd., (HCL) with standard peripherals such as two 80 MB disk drives, a line printer, a tape drive and an off-line data entry system; an analog interface subsystem and a set of programmable low pass filters and gain amplifiers.



The first Indian made Jaguar (Shamsher)

The SED's Long Light Canard Research Aircraft will be ready for flight trial in near future. It will utilize the novel combination of fibreglass in the form of undirectional and woven fabrics, a coldcuring epoxy resin and light foams as the fabricating material. The aircraft will undergo detailed tests of canard configurations, which are not only the most scientifically advanced for some types of civil and military planes but are also being increasingly used elsewhere too.

Recent efforts in the Structural Science Division of NAL are concerned in obtaining a better understanding of the composite materials with a view to their application for developing load carrying members of airframes. Carbon fibres, with their extremely high strengths and stiffnesses, are being developed.

While the Structural Science Division is concerned with the use of materials, with given properties to build optimum structures, the Materials Science Division of the laboratory has been concerned with two aspects of materials. They are (a) developing new materials and novel techniques of fabrication, and (b) seeking answers to the important questions why do materials behave the way they do insofar as their mechanical properties in service are concerned? In the first category, advanced materials developed at NAL are new fibres belonging to the aramid group, synthesis of hard materials like the cubic-boron nitride; infrared transparent glasses, infrared sensitive materials, high purity chromium. It is also developing of electrochemical milling machines (ECM) and spark erosion machines (SEM) which will help in production of aeroengine blades of hard materials such as nimonics.

The division has developed aircraft, aerospace structural hardware such as missile nose cones and randomes for electronic counter-measure pods. The division is concentrating mainly on advanced composites like carbon epoxy which are finding increasing application in aircraft structural hardware. This is particularly relevant in view of the LCA project. Aluminium-lithium alloys are potential candidate materials for the LCA air-frame. Laminates made out of Kevlar-49 fibre and aluminium-lithium alloy sheets will improve the fatigue and fracture resistance and lead to 10 per cent weight saving. Use of Fralial is expected to result in a weight saving of nearly 20 per cent. Hence, Fralial may prove to be a potential air-frame material. Two major projects involving use of carbon expoxy composite are currently in progress at NAL. They pertain to design and development of composite rudder for the MIG-21 and relates to design and development of a composite rudder for Dornier-228 transport aircraft.

The second category of problems regarding the mechanical properties of materials in service are of fundamental importance in aeronautics. Ever since its inception, the laboratory has been involved with these problems, generally classified as problems in fatigue and fracture. It has undertaken extensive base and applied research, and used this knowledge to determine the satistically guaranteeable service life of an aircraft such as the Gnat and the Ajeet.

Another aspect of the studies of the mechanical behaviour of materials is the failure analysis activity of NAL. The analysis has become a powerful tool to obtain safe operating conditions and longer life through improvement in design by a study of the failed parts. It has also become a powerful tool to pinpoint the causes for failure and establish responsibility for failures in accident investigations. The failure analysis group of the NAL has been associated in investigations of several air accidents including crash of Air India Boeing 747 Kanishka in 1985, off the coast of Ireland.

Since its inception, ADE has done a commendable job of handling its responsibilities. In response to the Air Force needs ADE had undertaken the development of motion based simulators and pilotless target aircraft on which the work is still going on. It had developed target drones, rocket pods, etc. The ADE is also taking major responsibility for the systems and avionics development for the LCA programme.

The ADE carries out design and development programmes on all other aspects of combat aircraft such as aerodynamics, structures, flight controls, avionics, air armaments and flight simulation. It is a multi-disciplinary laboratory comprising specialists in flight mechanics computer sciences, electronics, control engineering and mechanical engineering in almost equal proportions. ADE's successful research and development activities in the last decade provide the background to its present programmes on combat aircraft systems.

A Head-up Display (HUD) developed by ADE has already been flight evaluated in fighter aircraft. System design capabilities have been built up in the area of airborne electro-optic sensors. Flight simulation is of major interest in which ADE not only designs systems for training of aircrew but also provides simulation support in the aircraft design and engineering cycle. Advanced concepts in flights control systems such as fly-by-wire, are being studied. A reusable rocket pod developed by ADE is now entering large volume production. The development of a Pilotless Target Aircraft for exercising the guns and missile systems of the three services is a major programme at ADE. Already an air-launched high speed system has been developed and is undergoing evaluation.

The Gas Turbine Research Establishment (GTRE) is engaged in the development of an advanced technology jet engine for the LCA at an estimated cost of Rs.1,000 million. The expertise built at GTRE over the years in major activities such as the design and flight testing of the engine provides a confident base for this ambitious project. In addition to numerically controled machine tools, GTRE is adequately equipped with facilities like electron beam welding and multispindle blade milling and development of advanced components of the engine with the help of extensive use of computer aided design techniques. The country is also involved in developing an Airborne Warning and Control Systems (AWACS) aircraft and several missiles programmes.

LCA is expected to take the country into 21st century as a developed country in aeronautics at a relatively low cost and in the process bridge the technology gaps that have developed over the years. It is hoped that the government will certainly balance the risks it takes with the opportunities and challenges it offers, and have the will to pursue the ambitious technological goals it is setting for itself.

In the development of Light Combat Aircraft (LCA), which will have high manoeuvrability and capability of holding its own in a close combat or in a medium-range missile combat environment, NAL is playing a key role in the aerodynamic design of the aircraft. When it flies, LCA is expected to be a relatively low cost, light weight combat aircraft, incorporating modern technologies such as fly-by-wire control systems, relaxed static stability, aluminium-lithium alloys for its fuselage and carbon fibre composites for its wings, etc. The first prototype of the LCA is expected to fly in 1991 and it will join the IAF in 1995.

Significant efforts continue to be made at the Hindustan Aeronautics Ltd. to evolve indigenous substitution to replace imported items in the current production programmes, it is now engaged in design, development, production and overhaul of aircraft, its engines, avionics and accessories. The wide product mix of HAL ranges from rotary and fixed wing aircraft of indigenous design to licence manufacture, jet and piston engines to power them; matched avionics and accessories to obtain operational capability. HAL also manufactures supersonic aircraft designed for specific strike combat interception, observation and surveillance roles equipped with advanced technology plants, avionics, accessories and armament.

Major products manufactured at the HAL are: Jaguar, Kiran MIG, BIS, MIG 27 M and HBT 32 aircraft, Chetak and Cheetah helicopters, aero-engines for various aircraft avionics, accessories and instruments, forgings and castings and parts required for the space programme of the Indian Space Research Organisation. HAL is a major participant in LCA development programme. Apart from LCA, HAL would be the agency responsible for the manufacture of Marine Gas Turbines up to 25 MW range. Projects for manufacture of Jaguar, MIG 27 M and Dornier aircraft involving a capital outlay of Rs. 240 crores are in the implementation state. The design and development of LCA is under progress. The Aerial Delivery Research and Development Establishment (ADRDE), located at

Agra, designs systems and appliances for aerial delivery of men and material. Development of parachute based systems for missions such as air-dropping of field guns, and the recovery of unmanned aircraft is the major activity of the establishment. One of the notable achievements of ADRDE is the development of brake parachutes for fighter aircraft.

Defence Electronics

Electronic Warfare (EW) is the focal theme of the Defence Electronics Research Laboratory, Hyderabad. The laboratory is engaged in several technique-oriented investigations in the EW area while developing at the same time hardware systems to meet the requirements of the services.

The Instruments Research and Development Establishment (IRDE), which is an active centre on optical and electro-optical systems, has recently created a Technology Transfer Centre (TTC) which will function as a dynamic technology and management interface in the process of organising regular production of the electro-optical instruments developed.

The Defence Science Centre (DSC) and the Solidstate Physics Laboratory (SPL), both at Delhi, are the two upstream laboratories engaged in anticipatory research as well as engineering development in the field of solid-state materials and devices. Several state of the art technologies such as gallium arsenide devices, infra-red detector arrays, charge coupled devices, acousto-optic devices, Yag laser crystals and gas laser sources are being developed. SPL has developed silicon solar cells which are likely to be used by the Indian Space Research Organisation. Several ferrite and garnet materials have been developed for microwave applications.

The Research and Development Establishment (Engineers), Dighi, near Pune, has developed a family of bridges capable of supporting a range of loads in light weight weldable aluminium alloys and the Vehicles Research and Development Establishment, Ahmednagar, has designed and developed a number of armoured and special purpose wheeled vehicles, tank transports and traillers to meet the mobility needs of the armed forces.

The Snow and Avalanche Study Establishment (SASE), Manali, is engaged in the pioneering role of studying, for casting and finding ways and means to control avalanches in the snow-bound areas to control avalanches in the snow-bound areas of western and central Himalayas. SASE, with its chain of high altitude observation points, has been issuing regular avalanche warnings to save men and materials.

The Defence Institute of Fire Research (DIFR), Delhi, besides imparting training in various aspects of fire fighting and prevention to civilian and service personnel, also developed efficient equipment for fire fighting.

The Naval Physical and Oceanography Laboratory (NPOL), Cochin, has made significant contributions in understanding the ocean environment knowledge that is essential to the development of underwater sensors and weapon system. Oceanographic instruments developed by the laboratory are being used extensively to collect data in respect of speed and direction of ocean currents, attention of visible light in the sea, sea wave and tidal records, and the sound velocity profile. The expendable bathythermograph, developed by the laboratory, is being used by naval ships to determine the variation of temperature with depth—an inout that is critical to the underwater fire control problem.

The Naval Chemical and Metallurgical Laboratory (NCML), Bombay, provides the Navy with technology inputs that help prevent hauls of ships and submarines from corrosion and the hostile sea water environment. The laboratory has successfully developed underwater anticorrosive and antifoulding paints in addition to the cathodic protection technology. The laboratory has also developed special techniques for the insitu welding of titanium and other reactive metals and alloys. Using these novel techniques, it has been possible to weld repair and salvage critical and costly marine components. Noteworthy work has been done on ceramic (PZT) transducers for the solar system of NPOL.

The Naval Science and Technological Laboratory (NSTL), Visakhapatnam, has developed a triple torpedo tube launcher that is planned for fitment on the latest ships of the Navy. A high speed towing tank to undertake model studies on high speed vessels and other hull forms, a shock tank to study the effect of underwater explosion, a magnetic measurement room to undertake design of ship degaussing systems, are amongst some of the ship research facilities that are now being set up at the laboratory.

Innovative methods developed to determine their radiated noise levels have been adopted by the Navy. The torpedo technology developed by the laboratory has led to the development of a deep mobile target which manoeuvres like a submarine at great depths responds to sonar transmission of various kinds. A three-buoy system has been developed to track two underwater vehicles simultaneously to the designed accuracy. A test range to evaluate performance of underwater weapons is being set up.

Materials

Nickle base alloys and special alloys have been developed by the Defence Metallurgical Research Laboratory (DMRL), Hyderabad, for aircraft components and for armour applications respectively. Based on this technology, Hindustan Aeronautics Ltd. has set up manufacturing facilities to produce metallo-ceremic rotor brake-pads and bi-metallic stator brake-pads for fighter aircraft. The laboratory's expertise in intricate castings in aluminium and magnesium alloys has also contributed to the country's space research programme. The current programme of DMRL include the development of advanced high temperature nickle base alloys, titanium alloys by conventional vaccum are melting as well as by powder matallurgy, dispersion strengthening of nickle base alloys by mechanical alloying, inert gas atomisation for superalloy powder production, hot isostatic pressing of powders, investment casting of gas turbine blades, thermal barrier coatings on turbine blades by plasma spraying, electroslag casting of hollow shapes, liquid forging superplastic forming diffusion bondings.

The Defence Materials and Stores Research and Development Establishment (DMSRDE), Kanpur, undertakes research and development work in nonmetallic materials, textile and general stores. It has developed several special purpose adhesives, rubber components, lubricants and greases. Products for the prevention of corrosion in cooling systems of engines and recoil systems of guns have also been developed. A new set of army clothing in disruptive design developed by the laboratory provides comfort to the soldier without sacrificing operational efficiency. Extendable frame supported tents with unobstructed floor space and sufficient head-room developed by the laboratory are being used by the Army. The laboratory has also developed a variety of other items of general stores like boots for anti-mine operations.

Life Sciences

In the field of health, the Institute of Nuclear Medicine and Allied Sciences (INMAS), Delhi, has developed expertise in the . areas of radiopharmaceuticals, radioimmunoassay, radiobiology, health physics, bioengineering and experimental medicine. It renders medical advice to the members of the armed forces as well as to others. The concept of radio-iodine split dose therapy in the management of hyper-thyroidism, introduced by the institute's prestigious Thyroid Research Centre has been well accepted in India and abroad.

The Defence Institute of Physiology and Allied Sciences (DIPAS), Delhi, developed methods of increasing the lighting efficiency, safety and comfort of the armed forces. Systematic studies at the institute on high altitude acclimatisation process have helped in the understanding of metabolic changes that take place while staying at high altitude areas. The neutral mechanisms of adaptation to high altitude with special reference to the role of autonomous nervous system have also been investigated by the institute leading to useful conclusions.

The Defence Institute of Psychological Research (DIPR), Delhi, has formulated selection procedures being adopted for recruitment in the armed forces. It has also devised and standardised suitable psychological tests for selection of officers and other ranks of the three services.

The Defence Research and Development Establishment (DRDE) Gwalior, is concerned mainly with toxicology and environmental pollution of importance to the defence services. It has devised procedures for identifying bacterialysis principle, capable of producing 1,250 litres of potable water per hour from brackish water. A desert desalting kit capable of providing 4 litres of potable water from brackish sources developed by the laboratory now forms part of the personal kit of the soldier. An emergency survival kit to provide drinking water from sea water has been developed for use by the Navy and the Air Force.

The Defence Bio-engineering and Electromedical Laboratory at Bangalore studies problems related to bio-engineering aspects of aviation, and also develops medical electronic instrumentation. Anti-G suits, oxygen masks and protective helmets have been developed by this unit. An automatic inflatable life jacket is being designed. In the field of electro-medical instrumentation, a variety of equipment for patient monitoring, cardiac care, cardiac pace-maker, etc., have been developed. Presently, a medical data processing and automatic diagnosis system is under development.

The studies on the etalogy of frostbite on exposure to in high altitude and other inhospitable regions have been carried out to study various problems of the local agriculture and animal husbandry aspects. The laboratories have standardised practices for the cultivation of vegetables in the various agro-climatic zones and have evolved new strains of agricultural products suitable for cultivation in these areas. Poultry farming and animal husbandry suited to local conditions are also being investigated. The interesting interaction between these scientific laboratories and their rural surrounding is visible in the changes in the socio-economic life pattern of the people of these communities.

Weapon Systems

Trends in warfare over the last decade have clearly established rockets and missiles as crucial armaments in the both offensive and defensive roles. The Defence Research and Development Laboratory (DRDL) at Hyderabad has built up the technological base and facilities required for designing, developing and testing the diverse subsystems of guided missiles. The laboratory has developed large thrust rocket motors with solid and liquid propellants. Expertise has been established by the laboratory in command guidance, semi-active homing and inertial guidance. In the area of flight control, competance has been built in aerodynamic control as well as thrust vector control. Three and four axis stablished platforms have been succesfully test flown. Confident of its abilities, the laboratory has recently launched an integrated missile developed programme that will pool the efforts of a large number of defence science laboratories.

The Combat Vehicle Research and Development Establishment (CVRDE) at Avadi near Madras has been entrusted with the task of developing the Main Battle Tanks (MBT) to serve the Army in the late 1980s and 1990s. The MBT has been designed to have greater fire power, higher mobility and enhanced immunity than similar systems available now. CVRDE is the systems co-ordinator of this major project involving the co-operative efforts of several defence laboratories. In addition CVRDE has direct development responsibility covering vehicle design, its propulsion unit and auxiliary systems. The establishment is also engaged in the development of other armoured vehicle variants to fulfil different operational roles.

The Armament Research and Development Establishment (ARDE) at Pune has a long record of over twenty-five years of successful development of armaments required by the three Services. Some of the important armament designed by ARDE which have been inducted into service are the well-known Ishapore Rifle with its ammunition, 75/24 pack Howitzer and its ammunition for use in the mountaineous regions, 105 mm Indian Field Gun, unguided rockets for air-to-air and air-to-ground use. Currently ARDE is actively engaged in the development of a Fin Stablished Armour Piercing Discarding Sabot, a family of small arms with matching ammunition, a powerful gun for the Main Battle Tank, a rapidfire multi-barrel rocket system and several more weapons. A special explosive bore hole charge developed by ARDE has been utilised by the Oil and Natural Gas Commission in petroleum exploration. Armament design is a multi-disciplinary effort and for this purpose ARDE maintains a continous interaction with other defence establishments.

Working in close liaison with ARDE the Explosive Research and Development Laboratory (ERDL), also at Pune, has developed a wide range of military explosives for guns, mortars, rockets and missiles. Various pyrotechniques for producing smoke, illumination, incendiary, delay and flare have been standardised. A high energy propellant giving better penetration and greater range is being developed. The semi-combustible cartridge cases developed by ERDL will save valuable brass. ERDL designed protector liner around the propellant in the cartridge case which extends gun barrel life significantly by minimising erosion. The charge line mine clearing device developed and manufactured by ERDL is of importance to the infantry. The large size solid propellant grains developed by the laboratory are used in missile development programmes. A notable event is the successful development of a process to manufacture high melting explosives.

The Proof and Experimental Establishment (PEE) at Balasore and the Terminal Ballistics Research Laboratory (TBRL) at Chandigarh are the specialised establishment which provide the essential ballistic data and performance feedback to the agencies developing armaments. Utilising advanced instrumentation such as high speed photography and flash radiography, TBRL studies the performance of armour defeating projectiles, blast damage, fragmentation and other problems of detonics of explosives. PEE located on the sea range conducts performance evaluation of all newly designed guns and ammunitions and is equipped to conduct several types of ballistic tests such as projectile velocity, chamber pressure fuse functioning and armour penetration.

Engineering

Terrain intelligence requirements of the services are met by the Defence Terrain Research Laboratory (DTRL) at Delhi. Using modern techniques of data collection, storage and retrieval, functional maps and appreciation reports on various terrain, such as high relief mountains, riverine, plains, plateaus, deserts and coastal tracts, are prepared. The spin-off to the civil sector from DTRL's work is in the field of highway engineering, route alignments, town planning, post earthquake terrain assessment and flood zoning. DTRL is an active participant in national projects such as the study of the seismotectonics of the Himalayas and multiple data base studies in the Gandak basin.

The Research and Development Establishment—Engineers (R & DE-E) at Dighi near Pune is engaged in developing bridges, trackways and other equipment needed for the army's mobility. The establishment has developed a family of bridges capable of supporting a range of loads in light-weight weldable aluminium alloys. Trackways for use on soft grounds fit to support a tank have been developed. Several heavy engineering equipment such as high altitude simultation chambers for pilot testing, pressurised chambers for simulation of water depths, mechanical mine layers and high rise static and mobile masts for radar antennae have been developed. The establishment has extensive structural testing facilities and is setting up a fluid power test facility—the first of its kind in India.

The Vehicle Research and Development Establishment (VRDE) at Ahmednagar has designed and developed a number of armoured and special purpose wheeled vehicles, tank transporters and trailers to meet the mobility needs of the Armed Forces. This establishment has one of the best test track facilities to evaluate the performance and road worthiness of vehicles designed in the defence and civil sectors. Currently VRDE is active in the areas of electronic vehicle management, high specific output including turbo-changing, hydro-pneumatic suspension, hydraulic and electro hydraulic controls, torque convertors, etc. Work on ground equipment for missile systems has also been taken up.

Systems Analysis and Information Management

In the field of Systems Analysis, Training and Information, the Centre for Aeronautical Systems Studies and Analysis (CASSA) in Bangalore carries out performance assessment and cost effectiveness studies related to aircraft missiles and other major systems. Software models developed by this centre have been used successfully in the assessment of air threats, formulation of ORs and optimisation of force mix. The Institute for Systems Studies and Analyses (ISSA) at Delhi carries out studies on operational research problems of immediate relevance to the Services. The institute assists the armed forces in finding solutions to problems such as those related to the shelf life of ordinance stores. Several important studies have been carried out on the expectiveness of weapon systems utilising data collected by ISSA teams visiting.

The Defence Institute of Works Study (DIWS) at Mussoorie has now expanded its activities from the initial role of imparting training in work study. It makes significant contribution to the development of the human resources by conducting training courses for the young scientists and short capsules in work study and productivity sciences for the senior officers. New courses in financial management, value engineering, administrative management have also been started recently. DIWS provides consultancy services on a variety of subjects such as material handling problem of the Air Force, modernisation of the Army base system for major R&D projects.

The Institute of Armament Technology (IAT) at Pune has a tradition of imparting effective training for the armed forces for many years. The emphasis placed at IAT on innovation through design exercises has yielded excellent training value. The institute conducts specialised courses for officers from the Services as well as civilian scientists of DRDO. Trainees are also drawn from the production and inspection organisations of the Ministry of Defence. More recently, IAT has taken up the responsibility of conducting the orientation courses for the new entrants to the scientific cadre of DRDO.

To meet the increasing demand for computational facilities, DRDO is establishing Regional Computer Centre (RCC). Plans are also being made for networking of the regional computers and for efficient interaction with the national information systems.

The central agency for collection, processing and dissemination of scientific information is the Defence Scientific Information and Documentation Centre (DESIDOC), located at the historic building of Metcalfe House in Delhi. The Defence Science Library has a large collection of books, journals, periodicals and technical reports. The centre now operates a computerised information retrieval systems and provides access to international network.

Lasers

LASERS, ASSOCIATED by many with the Strategic Defence Initiative (SDI), popularly known as Star Wars, are being extensively used in India for peaceful purposes.

The laser beams which are a coherent beam of light intense enough to vaporise the hardest material ever known, are being used to drill holes in diamond, to weld detatched retina of eye, and destroy malignant brain tumours located deep inside the brain or in the spinal cord and to transmit information.

Over 90 research institutions, universities and a few private companies in the country are working on various aspects of lasers, like their fabrication, development of laser materials and their applications to different fields like metrology, communications, medicine and isotope separation, and in basic research.

Work on fabrication of lasers has been taken up at a number of institutions in this country and they have successfully fabricated nitrogen, carbon dioxide and helium-neon lasers. Scientists believe that indigenous commercial production of nitrogen, argon, helium, cadmium and nitrogen-pumped dye lasers (all by Central Electronic Ltd., Sahibabad), carbon dioxide laser by Advani Oerlikon and Joyti Ltd., Helium-neon by Electronics Corporation of India Ltd., may soon become popular and reliable.

Attempts to develop lasers in this country started as early as 1964. The activity could not generate enough momentum in the first decade, but has started picking up since the mid-seventies. Though the total efforts are still at a modest level compared to other advanced countries, many institutions and research organisations have taken up the know-how or started their own R&D activity for production and marketing of lasers.

While the argon laser prototype was developed by IIT, Kanpur, Banaras Hindu University, Varanasi, made a pulsed carbon dioxide laser for work on photo-chemistry.

Marathwada University developed a water dielectric coaxial cable pulsed CO_2 laser. Bhabha Atomic Research Centre has also done extensive work on CO_2 lasers. They developed the prototype of a low power helium-neon laser and transferred the know-how to ECIL, Hyderabad. Besides several other institutions have also developed helium neon lasers of various powers. Numerous centres have fabricated nitrogen lasers for their own experiments. They include Kerala University, IIS, Cochin University, IIT, Bombay, and BHU, Varanasi. Karnataka University developed an inexpensive nitrogen laser of power 100-200 KW.

In the field of semiconductor lasers, which differ from other lasers in the energy levels and also considered as most compact of all known lasers, work is going on at BARC and Solid State Physics Laboratory, Delhi.

Few laboratories in India namely BARC, Instruments Research & Development Establishment, Defence Science Laboratory have developed various kinds of solid state lasers. They have developed Ruby, Nd: Yag and Nd: glass lasers to varying degrees from imported components. The Central Glass and Ceramic Research Institute, Calcutta, is producing Nd-doped glass and also the corresponding UV shielding glass to prevent solarization of the Nd: glass. Advani-Oerlikon, Pune, is developing high power Nd: glass and Nd: Yag lasers for production and marketing as industrial lasers for cutting, drilling and heat treatment.

BARC, Bombay, IIT, Kanpur, and IIS, Bangalore, have been the major centres with extensive facilities for development of lasers and laser components. Facilities like sophisticated glass blowing shops and capabilities to work on quartz-system, optical shops for grinding and polishing of flats, and optical mirror coating facilities have been set up.

Among the most active centres where theoretical work on lasers or related topics is being carried out are the universities of Allahabad and Hyderabad, IIT, Delhi, BARC, Bombay, Tata Institute of Fundamental Research, Bombay. Among other centres where some theoretical work on lasers is going on are: Calcutta University, SV College, Delhi, IIT, Kharagpur and Marathwada University.

Lasers have innumerable applications outside pure science. But due to limited availability of lasers and components in the country the activity is at present very low except probably in the defence field, for which details are not available for obvious reasons.

Optical Communications

IIS, Bangalore, is working on the broad engineering aspect of wave guides, fibre-optics links and sensors and optical memories, laser Doppler anemometry for electrical, single processing, and efforts of various factors in transmission of laser beam through the atmosphere. IIT, Delhi, has planned for optical waveguide fabrication facility and plan extending and upgrading the experimental techniques for the characterization of the first and second generation single and multimode optical fibres and optimization of optical fibres and development of glass fibres for communication. Another group at the centre is developing a 5 km-long link of fibre optical digital communication system. It is also working on image restoration, reconstruction and data compression, and has completed an optical processor for synthetic aperture radar signals.

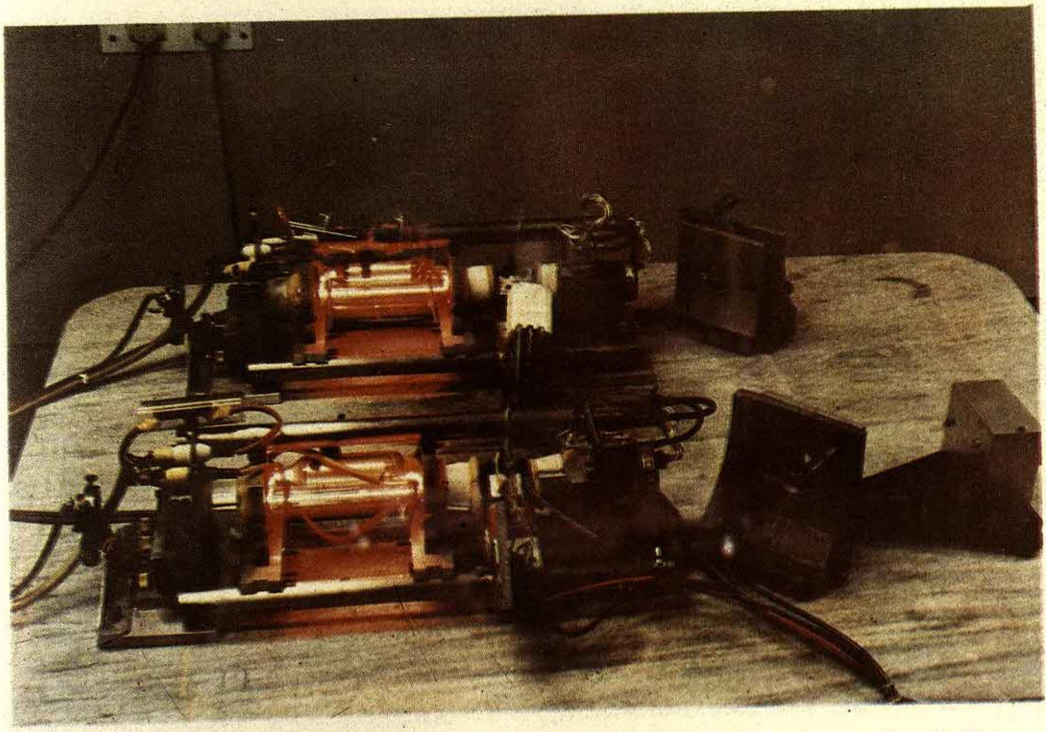
IIT, Madras, is studying the effect of turbulence on open-air laser communications, and is making feasibility studies on underwater communication, and in infrared (GaAs) laser beam link between two distant computers using pulse-code modulation. They are also developing a fibre-optics laser current transformer.

Indian Space Research Organisation, Ahmedabad, has extensive involvement in optical data processing and plan to set up lidar systems for satellite tracking and satellite geodesy work. A complete mobile lidar system based on ruby laser has been built by Vikram Sarabhai Space Centre, Trivandrum, for remote sensing up to 60 km height. They have also built another lidar system based on argon laser to operation on a bistatic mode.

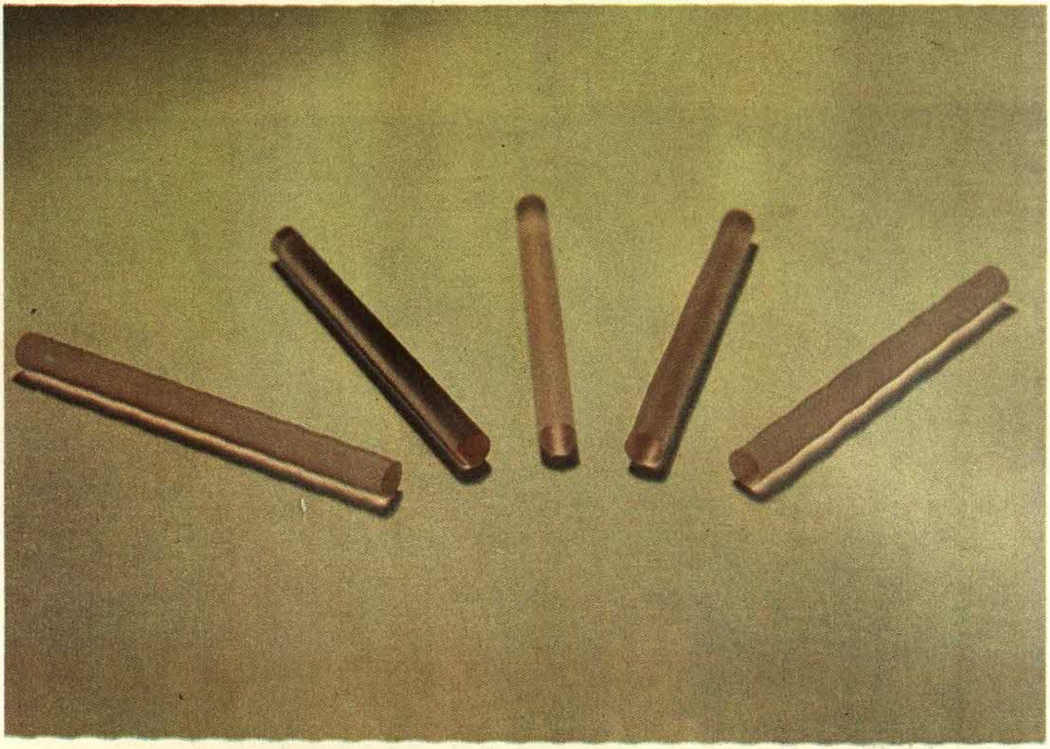
Engineering applications: IIS, Bangalore, has used its lasers for drilling and annealing experiments and for micromachining of various metals and non-metals. Advani Oerlikon, Pune, plans to produce and market industrial laser for cutting, drilling and heat treatment. IIT, Kanpur, is making feasibility studies on machining with their CO_2 laser and IIT, Madras, is developing a laser system for cutting on extended polystyrene material.

In the field metrology, Central Machine Tools Institute, Bangalore, is measuring the accuracy of machine tools with lasers and Raman Research Institute, Bangalore, is using laser system in the metrology work for their radiotelescope. Both are developing the related software. IIT, Madras, has designed a tool maker's microscope based on lasers and National Physical Laboratory, New Delhi, has developed line and end gauges as standards of length. Reactor Research Centre, Kalpakkam, is working on measurement of dimensional changes using holograms and IIT, Kanpur, is ~~studying~~ the general use of lasers for meteorology. Jyoti Ltd., Baroda, have made a laser alignment system and have marketed 50 of them to users.

Holographic work on various aspects like imaging, microscopy, conoscopy, interfermetry, etc., is being done at Bombay University, Osmania University, Kashmir University, IIS, Bangalore, IIT, Bombay,



Iodine Stabilished Helium Neon Laser at National Physical Laboratory, New Delhi



Laser Glass Rods—CGCRI, Calcutta

IIT, Delhi, IIT, Kanpur, IIT, Kharagpur, IIT, Madras, BARC, Bombay, IRDE, Dehradun, RRC, Kalpakkam and Institute of Armament Technology, Pune.

The Survey of India is making use of lasers in range finding. The organisation also trains their staff for use of lasers in plumbing, surveying and alignment of tunnels. BARC, Bombay, has developed range finders based on ruby and Nd: Yag lasers.

In the area of measurements of pollutants through Rayleigh scattering, mention may be made of air pollution measurements at IIT, Madras, and identification of macromolecules and viruses by laser diffractometer at IIT. Kharagpur, and IIT, Madras. Laser remote sensing in general and determination of parameters of solid particles suspended in air are being carried out by BARC, Bombay. If and when advances in lasers are achieved in the country it would not only benefit India but the world as a whole. This will enable India to face the challenges of 21st century with vigour and confidence.

Electronics and Instrumentation

INDIA HAS now expertise to manufacture modern electronics and precision instruments both for research and routine application in diverse fields like nuclear energy, space and defence.

While scientists of the Bhabha Atomic Research Centre in Bombay have developed a number of control and instrumentation system for the nuclear reactors like Dhruva and Purnima II, over half a dozen Defence Research and Development Laboratories have designed and developed modern electronic and precision instruments—"eyes and ears of the defence system"

The BARC scientists have also designed and developed a number of sophisticated special purpose instruments for the Reactor Research Centre at Kalpakkam, Nuclear Power Stations, Fuel Reprocessing Plant, Radiation Medicine Centre, Indian Institute of Astrophysics and Defence Electronics Applications Laboratory.

A wide variety of sophisticated equipment, useful for research as well as for routine applications in diverse fields, have also been made by BARC scientists. Important among them are the TDC-312 computer based gamma scanner, high efficiency solar cells, the microcomputer based metallographics analysers, the computerised plant data acquisition system, microprocessor based nuclear instruments like liquid scintillation spectrometers, multichannel analysers, mossbauer and auger electron spectrometers, field ion microscopes, quandrupole mass analysers, high power electron beam furnaces, plasma torches and infrared sentitive image converter tubes, various pieces of equipment like microprocessor based thermoluminiscent and film badge dosimeters, radiation and contamination monitors, wide range survey meters and infrared gas analysers have been developed by BARC for personnel and environment monitoring.

Besides, BARC has also set up the Reliability Evaluation Laboratory which offers services for testing and measuring electronics components and equipment to different units of the Department of Atomic Energy and to other institutions and industries located in the country.

The Indian Space Research Organisation has developed electronic packages and control system for indigenous satellites and launch vehicles. Recently, the ISRO has designed and developed packages for augmented satellite launch vehicle (ASLV). Many of these packages may be used for polar satellite launch vehicle (PSLV) with minor modifications.

An optical range finder system for T Theratron 80 R Cobalt 60 treatment unit has been designed and developed at the Central Scientific Instrumentation Organisation (CSIO) and installed at the Post Graduate Institute of Medicine, Chandigarh. Two proton precision magnetometers, designed and developed at National Geological Research Institute (NGRI), the know-how for which had been passed on to entrepreneurs, were modified suitably for deployment in Antarctica. A six component strain guage balance to be used for measuring the loads on bodies towed under water in the towing tank facility at the Naval Architecture Division of IIT, Madras, has been designed, fabricated, guaged and calibrated.

The Electronics and Radar Development Establishment (ERDE), at Bangalore, has developed and established production of a light weight field artillery radar as well as an unit for an existing fire control system. The present range of its development programmes covers surveillance radars for low level air defence, airborne interception systems, as well as radars for the detection and tracking of naval threats. Digital signal processing and advanced antenna techniques such as phased arrays are the essential elements on which the sophistication of the future radars depend. The scientific contributions of ERDE in these fields are helping to move the state-of-the-art forward. An outdoor test range is available for the evaluation of antenna performance. Besides radars, ERDE has a powerful group on digital communication and switching techniques. One of the recent achievements of this group is the development of an automatic electronic switch which is now entering production. It also pays attention to the development of component technologies.

Electronic warfare is the focal theme of the Defence Electronics Research Laboratory at Hyderabad. The laboratory is also engaged in several technique-oriented investigations in the electronic warfare area while developing at the same time hardware systems to meet the requirements of the services. The present capabilities of the laboratory are built on its successful experience in the development of secrecy systems, secondary surveillance radars and battle field surveillance radars. Several electronic warfare systems are presently under development and evaluation.

The Defence Electronics Application Laboratory (DEAL) at Dehradun was given a revised charter in 1976. Known as the Himalayan Radio Propagation Unit (HRPU) until then, the laboratory was engaged primarily on studies with regard to communication problems in hilly areas. Alongside, HRPU also took up the development of a troposcatter communication system and established its capability in this area. A high power microwave amplifier developed by HRPU is now being manufactured.

Under its revised charter, DEAL undertakes investigations and development activities covering image processing techniques as well as modern methods of scatter communication. An airborne solid-state microwave refractometer developed by the laboratory in collaboration with the National Physical Laboratory, New Delhi, has been successfully flight evaluated. Some projects on communication systems using troposcatter and meteoric scatter are now in the advanced development stage. Studies on telecommand and telemetry systems using sophisticated digital modulation techniques have also been taken up.

The Instruments Research and Development Establishment (IRDE), Dehradun, which is an active centre on optical and electro-optical systems, has also now engaged in the development of electro-optical system such as low light level TV, thermal imagers and laser ranging equipment. In addition to a large number of user oriented projects, IRDE carries out several investigations in advanced optical and electro-optical techniques involving holography and fibre-optics. These investigations enable the establishment to undertake the development of major integrated fire control systems using electro-optical sensors and detectors for various weapon platforms. Currently, the IRDE is engaged in development of instruments, sights and fire control system for the Main Battle Tank (MBT). IRDE has recently created a Technology Transfer Centre which function as a dynamic technology and management inter face in the process of organising regular production of the electro-optical instruments developed.

Progress in the development of electronic and electro-optical systems is influenced critically by the advances made in the science and technology of materials and components. The Defence Science Centre and the Solid State Physics Laboratory (SPL) both in Delhi are the two upstream laboratory engaged in anticipatory research as well as engineering development in the fields of solid state materials and devices. Several state-of-the-art technologies such as gallium arsenide devices, infrared detector arrays, charge coupled devices, acousto-optic devices, Yag laser crystals and gas laser sources are being built up.

SPL has created modern facilities for sophisticated semiconductor device fabrication facilities which include ion implanter, molecular beam epitaxy as well as E-beam, microfabrication. It has developed silicon solar cells, which have already been space qualified. Several ferrite and garnet materials have been developed for microwave applications.

In addition to its work on electronics materials and devices one of the notable achievements of DSC is the indigenous development of a process to manufacture UDMH and G fuel, as liquid popellants for missile.

The objective of national instrument development programme is on indigenous development and production of the instruments, updating of instruments to keep pace with the improvements, design and developments of more advanced novel instruments and establishment of science and technology base and production techniques.

The scheme of Regional Sophisticated Instrumentation Centres was initiated by the government during 1974-75 with the main objective of providing sophisticated instrumentation facilities to scientific community and to create and promote a culture in the country relation to use and maintenance modifications/improvement of sophisticated instruments. This scheme has gone a long way in catering to a wide spectrum of users from various education institutions, research institutes and industrial organisations. During the current year, the range of users has grown to cover almost all parts of the country encompassing various disciplines.

At present there are seven such centres at Bombay, Madras, Lucknow, Calcutta, Shillong, Chandigarh and Nagpur and four Specialised Instrument Faculties at Bangalore, Calcutta, New Delhi and Gauhati.

The Regional Sophisticated Instrumentation Centre, Bombay, has been providing facilities to a number of users from universities, national laboratories, research organisations and also from private sector. Most of the instruments available in the Centre are being utilised on extensive basis and some of the instruments such as NMR Spectro-Photometer continue to be operated in two shifts to meet the heavy demand.

The Regional Sophisticated Instrumentation Centre, Lucknow, provides analytical service to the research institutes, universities and other research and development organisations in the region. One of the major achievements of this Centre had been providing instruments facilities to small constituent colleges in UP, Bihar and MP. The Centre has installed a WM-400 WHz - NMR and Liquid Helium Facility recently. Orders for a new Scanning Electron Microscope have recently been placed.

The Regional Sophisticated Instrumentation Centre (RSIC), Madras, provides continuous analytical services to various internal and external users. Electronic technicians of the Centre have also been attending to trouble shooting work on several sophisticated instruments in and around Madras.

Contact training of operation and maintenance of instruments has been provided by RSIC, Madras, to technical staff of some of the users institutes delivering lectures on special research topics associated with the facilities available at the Centre. One of the major activities of technical staff had been servicing and maintenance of the sophisticated equipment.

The Regional Sophisticated Instrumentation Centre, Calcutta, has been providing facilities with regard to the most of the equipment already available in the Centre. However, there has been a slow progress regarding the installation and commissioning of new instruments already provided under the programme such as FT-NMR-EPR, TEM and Atomic Absorption Spectro-photometer.

The Sophisticated Instruments Facility located at Indian Institute of Science, Bangalore, comprises two equipment at present, viz., 270 MHz, FT-NMR and a 200 k Electron Microscope. The FT-NMR facility has, as in the previous years, maintained the records of being used on all the days of the year. During 1985-86, 375 proton and 279 carbon-13 requests have been fulfilled. A good amount of time has also been utilised by specialised lasers. Procedure for carrying out special experiments with the new computer has been evolved to suit the hardware available in the spectrometer. Software to carry out multiple quantum NMR experiments using large data size is under progress and it is expected that this development will lead to simplification of complex spectra, particularly in oriented systems. The facility has also been helping other neighbouring institutions in the maintenance problems of their equipment.

Electronics

The manufacture of radio receivers in the early 1950s heralded the beginning of electronics industry in India. Since then, considerable progress has been made and the industry's range now extends from manufacture of consumer and professional grade electronic components to the design and development of sophisticated equipment for aerospace and defence applications.

The country, now gearing itself to meet the challenge of the electronics revolution during the rest of the decade aims to reach an annual production level of Rs. 100,000 million by 1990, the end of the seventh plan period. From a predominantly consumer-oriented industry, electronics has diversified to include advanced systems governing computers, controls and instrumentation, besides telecommunication using advanced technology in integrated circuits.

The country entered the large scale integrated (LSI) circuits/very large-scale integrated (VLSI) circuits era in March 1984 with the trial production of the pulse dialler chip by the public sector Semiconductor Complex Limited (SCL). With an outlay of Rs. 500 million, the plant has contemporary facilities to fabricate the latest types of silicon chips.

In the longer perspective, the task force on LSI/VLSI has formulated as a goal the need to achieve one-micron capability of research and development to enable fabrication of one million components of a chip by 1990. The major elements of this programme include the setting up of a centre of excellence to provide a major thrust in research on process technology establishing a number of decentralised design centres, both to implement the silicon foundry concept and to develop computer aided design (CAD) facilities for VLSI. It will soon set up microprocessor application development centres. Another element would be the development of critical peripheral technologies like capital equipment, packing and materials/chemicals.

The state-owned, Bharat Electronics Limited (BEL), which produced the integrated circuits in 1971, has manufactured over 50 types of bipolar ICs so far. These include 20 types of TTL version and the remaining the linear type for application in TV, AM/FM radio multiplexing applications and voltage regulations. Besides, it has fabricated a prototype watch chip with LSI capability. While BEL has a vertical integrated facility covering design, mask making wafer fabrication, assembly and testing up to the level of MSI, SCL is building up a comprehensive production level and R and D base up to the level of LSIs/VLSIs.

Besides, there are several other organisations in the industrial and R & D sectors having strengths of various degrees in some or all segments of the technology. These include Central Electronics Engineering Research Institute at Pilani, Tata Institute of Fundamental Research, Bombay, and Indian Telephone Industries, Bangalore. In the academic sector, Indian Institutes of Technology at Bombay, Delhi, Kanpur, Kharagpur and Madras have got fairly extensive facilities. Barring a few gaps the infrastructure of these organisations taken together is capable of developing LSIs.

The country has competence to process wafers up to 7.5 micron, and comprehensive facilities exist at several organisations. Some of the research establishments have a few advanced equipment like ion implantation system, dry etching, vacuum sputtering and electron beam metallisation, which are in regular use. The wafer fabrication facility at SCL, is fairly contemporary and would process wafers of a 4-inch diameter. The facility would provide 5 micron chip to begin with and is expected to progress to 3 microns by 1987-88. Recently three firms in the private sector have come up for merchant supply of silicon single crystal and wafer for the microelectronics industry. They can produce wafers up to 4 inch diameter.

The Government has decided to set up a polysilicon plant of the National Silicon Facility (NSF) to produce ultrapure semiconductor grade silicon to meet the requirements of LSI/VLSI, as well as the Indian solar photovoltaic programme. NSF would also be responsible for stockpiling, production and research on all forms of silicon.

As regards computer systems, there are more than 2 firms manufacturing 8-bit systems and an equal number producing 16-bit systems. The state-owned Electronics Corporation of India Limited (ECIL) is one among them, making a significant contribution. The latest addition to ECIL's range is the 32-bit computer 'system 332' developed and manufactured indigenously. ECIL has also demonstrated the system for its remote graphic capability by linking through the Indian satellite APPLE to another system in a remote earth station. The company has developed special purpose hardware and software for a number of applications such as telephone directory enquiry, airlines flight data recording, criminal report generation of police and message switching. The prototype of a 32-bit computer of indigenous design capable of a performance speed of up to four million instructions per second (MIPS) is likely to be ready in next couple of months.

Recognising the important role of telematics and allied technologies, which provide means for communication with the masses, Government has set up a Centre for Development of Telematics (CDOT) to develop digital electronic switching systems. It is proposed to set up factories, each with a capacity of half a million lines. The project with an outlay of Rs. 360 million has been completed in 36 months.

As a forerunner, the Electronics Department has taken up an experimental project on Teletext in cooperation with the Ministry of Information and Broadcasting. During this experiment certain informations of public relevance are proposed to be transmitted along with Doordarshan transmission. The software required for data creation, updating and maintenance is being developed by the National Informatics Centre (NIC) of the Department of Electronics on an indigenous computer. This editorial software, with necessary software protocols, will interact with the transmission system. Efforts will also be strengthened to develop scripts for introducing Teletext in regional languages.

NIC provides computer-based management information system services and related support facilities to various ministries, departments and other offices of the government. Towards this objective it has developed a star-type computer network (NICNET) which links up 16 microcomputers and 20 interactive terminals located in different offices in Delhi. The CDC Cyber

170/730 System, procured with assistance from UNDP, serves as the central node of this network. The NIC computer system is now operational round the clock, with an average up time of 98 per cent. In its second phase of operation, NICNET will be extended to various state capitals to enable centre-state exchange of information.

For the first time in the country, the NIC has developed a computerised on-line patent information system based on bibliographic data available from the International Patent Documentation Centre (INPADOC), Vienna. The system creates information and multi-valued index directory files which facilitate faster and efficient retrieval of patent documents according to the International Patent Classification Code, date and year of publication, applicant's and inventor's name, the country of publication and title of the document. These bibliographic information can be obtained interactively or in batch mode. The system is based on documents recorded on magnetic tapes by INPADOC.

In a step towards data processing, NIC is setting up the INDONET, which is an integrated information management and distribution data processing facility, spanning the entire country. Under this project a computer network is being set up in Bombay, Delhi, Calcutta, Madras and Hyderabad. It will provide local computing facilities to small and medium sectors; highly specialised software in areas of engineering, designs, structural analysis and management sciences which professional organisation may share this sophisticated, diversified systems for developing software for export.

NIC is also establishing INTER-ACT, a UNDP sponsored project to develop and transfer know-how in systems engineering of real-time on-line computer-based systems, on the basis of technical cooperation among developing countries. The Computer Maintenance Corporation will be the implementing agency. Areas chosen include management of power systems and railway freight operations and meteorology.

For defence applications, in the area of communication systems both line and transmission equipment in HF, VHF, UHF and microwave frequencies in narrow and wide bandwiths are manufactured in various configurations. Such systems include fixed and portable antennae and line of sight (LOS) as well as troposcatter and satellite links. An integrated network of different communications systems employing both analogue and digital mode of transmission is also in advance stage of development.

In the area of radars and sonars, surveillance and tracking systems of diverse capabilities are in production. Radar frequencies range from L band to X band, and detection systems from a few meters to several hundred kilometers. The majority of production is for static and transportable systems on ground radars required by marine vessels as well as by military aircraft for both surveillance and fire control systems are also being produced.

Various control and command systems required by the three defence services and security agencies are in advance stages of development. Several components of the systems such as interactive graphic displays, real time data processors, and data bus are already being manufactured. Development plans include use of fibre-optic links for integrating various subsystems to minimise electro-magnetic interference in vast command and control systems. Besides, distributed data processing to minimise the loss of control in cases of damage or failure is also under implementation.

The production of defence-grade radio relay equipment has been enhanced with the participation of Hindustan Aeronautics Limited, Hyderabad, by increasing the BEL's production capacity and speeding up the design and production of next generation equipment. Both these organisations expect to commence production by 1987-88. Also production of radio trunk system is being taken up at the Punjab Wireless, Chandigarh, based on indigenous technique developed by LRDE.

The Government is setting up at BEL a division to produce higher power microwave tubes, namely 'klystrons', and travelling wave tubes, which constitute the basic devices in radar systems. With an investment of about Rs. 200 million, the unit would go into production within 30 months. Simultaneously, an R&D base is being set up to ensure that this is developed indigenously.

Microelectronics

There has been a radical transformation in the character of electronics industry in India, since the development of point contact transistors, in 1947-48, which laid the foundation of microelectronics.

Microelectronics in the country began appearing around 1970. Since then, it has made a remarkable progress in various fields. Innumerable applications have been successfully developed and systems used in industrial, scientific and other areas.

The manufacture of integrated circuits started in the country in 1971 when BEL fabricated the TTL 7420 IC with the know-how developed by Tata Institute of Fundamental Research (TIFR). At about the same time, BEL entered into a contract with RCA for know-how for ICs using bipolar and CMOS technologies. Since then, it has produced over 50 types of bipolar ICs and 16 types of CMOS ICs, many of them with indigenous efforts. Among the bipolars produced by BEL 20 types are of digital, TTL version and the remaining are of the linear type for applications in TV, AM/FM radio-multiplexing applications and voltage regulation.

The production of CMOS ICs started in 1977. The initial production was in 16-pin dual in-line packages, but subsequently a more reliable frit seal package was adopted which could meet the high reliability defence requirements. The CMOS ICs of BEL include eight chips in CD 4000 series which is a functional analogue of TTL 7000 series.

The ICs produced by BEL so far have SSI/MSI level of complexity. Besides, it has fabricated a prototype watch chip which has LSI capability. In the next few years, it proposes to manufacture microprocessors and memory chips using RCA's technology in addition to several new circuits of MSI level under design in-house currently.

The total investment by BEL on production facility including design, mask making, wafer fabrications, assembly and testing is Rs.70 million. Currently, its production is at 1 to 2 million level. At this level, it has considerable surplus capacity.

With the trial production of the pulse dialler chips by the public sector Semiconductor Complex Limited (SCL) in March 1984, the country entered the era of large scale integrated (LSI) circuits/very large scale integrated (VLSI) circuits. The plant with an outlay of Rs. 500 million, has contemporary facilities to fabricate the latest type of chips. the plant can produce 9 million devices a year, which can be raised to 20 million level by the addition of balancing equipment. However, the production in the initial few years is expected to be about 5 million units a year.

SCL has developed the 32 KHz clock chip and two kinds of semi-custom gate array circuits for alarm enunciator for Bharat Heavy Electricals Limited (BHEL) and KELTRON. Also, it has started the design of an electrically eraseable programme read only memory (EEPROM) in collaboration with the AMI Santa Clara, USA. It has entered into a technical collaboration agreement with AMI for the transfer of 5 micron CMOS and NMOS silicon gate technology, SCL also proposed to enter into bipolar area. The firm has signed an agreement with Rockwell, USA, for producing the 6502 microprocessor and associated peripheral chips, which will provide a major thrust to the computer, control and instrumentation industry. The company would undertake manufacture of a broad range of standard LSIs including calculator chips, telecom chips, microprocessors and speech synthesisers. The range of products would also include custom LSIs, modules and sub-assemblies based on LSIs, gate arrays and standard cells. While BHEL has already set up a vertically integrated facility covering design, mask making, wafer fabrication, assembly and testing up to the level of MSIs, SCL is building up a comprehensive production and R&D base up to the level of LSIs/VLSIs.

The BEL facility can be upgraded to LSI level by marginal additional investment. It has been carrying on R&D activities in addition to drawing on know-how provided by RCA. The R&D wing of SCL will undertake LSI/VLSI design and projects aimed at establishing and upgrading the capability of the company for meeting the various needs of the country.

The Central Engineering and Electronics Research Institute (CEERI), Pilani, a national laboratory for advanced research in electronics, started development work on ICS in 1967. Initially the work was limited to the study of certain components required for IC technology. Some simple circuits like TTL, gated were successfully fabricated in 1976, the institute initiated a programme on 'Advanced Technology for Semiconductor Devices' with joint support of Government of India and UNDP. It has since set up a complete line of equipment including computer aided design, mask making, wafer processing, ion implanter, encapsulation and testing. The total investment of capital equipment is about Rs. 50 million. Its basic interest lies in CMOS process and has already developed some circuits of LSI complexity.

TIFR has built up an active group and a strong infrastructure in IC design and fabrication. The first IC made in the country by BEL, the bipolar RRL 7420 was developed at TIFR in 1971. It has a composite facility to handle up to 40 micron geometries. It has, on its own efforts, fabricated an ion implantation system which can accelerate ions up to 150 KeV. It has also developed in-house, a computer aided design system which is similar to the commercially available system. Using this system, one can lay out and process LSI designs. The institution has processed software package from abroad and has implemented the same to aid LSI design. Some of these packages have been installed at other institutions also.

TIFR is currently working on CMOS metal gate and silicon gate technologies. It has in hand R&D projects on dielectric isolation technology, CCDs for imaging and design automation.

ITI has a strong group working in the design of LSI sub-systems using CAD. The institute is now setting up a pilot line for the fabrication of custom LSI circuits. The integrated facility costing about Rs. 40 million consists of CAD with interactive graphics mask fabrication systems, photolithography diffusion, ion implantation, assembly and testing systems. Its programme envisages development of process technologies adaptable for custom-design of sub-system in transmission, telephone and switching equipment. To begin with, it will establish a CMOS silicon gate 5 micron process. The company is already engaged in the development of expertise in semi-custom LSI design using standard cells.

The five IITs located in Delhi, Bombay, Madras, Kharagpur and Kanpur are premier institutions of engineering and technology with high academic standards matching well with leading academic institutions in developed countries. All these have basic processing facilities and are carrying out research studies.

Several industrial and research institutions have set up design capability up to LSI level. Organisations working in this area include ITI, Bangalore; BEL, Bangalore; CEERI, Pilani; TIFR, Bombay; SCL, Chandigrah; IIT Delhi; IIT Madras; and IIS, Bangalore. Some of them have developed a large amount of software packages. A number of software packages have also been acquired from abroad. However, gaps in the software packages still exist and need to be promoted before a comprehensive competence in CAD for LSIs can be claimed. These limitations are, however, not a major deterrent to LSI design.

Several MSI circuits have been laid with the use of CAD. Some of the circuits that have been laid are: TTL circuits (20 types), balanced modulator, audio amplifier, tape recorder circuit, CMOS cleek circuits, 3 pin regulator, telephone dialler, telephone amplifier and coder/decoder. While a number of these designs have gone into production, trial fabrication of some of them has been done at silicon foundries abroad.

TIFR has developed a CAD system with interactive facility which is equivalent to the commercially available system application. The institute is now engaged in the development of design automation system for VLSIs with complexities up to 10,000 gates. The project envisages development of design tools for geometric, logic and circuit design which can be integrated to realise VLSIs.

The government has launched a computer aided design programme with the support of UNDP. The outlay consists of Rs. 34 million contributed by Government of India and $1.54 million by UNDP. The programme, which is fairly general covering other areas as well, involves R&D for CAD applications in mechanical engineering, heavy engineering, real time control system, chemical engineering, metallurgical engineering in addition to electronics and integrated circuit design. The project which started in 1983 is of four years duration. It is being implemented at several centres and will provide training/education facilities for CAD and establish CAD software exchange system through software library.

The chip fabrication technologies have become fairly standardised the world over though unit processes/technologies are undergoing breakthroughs periodically. In view of the enormous possibilities of use of IC chips in new application on the one hand, and large investments required in chip production on the other hand, the concept of decentralised design centres and centralised design chip production facilities (silicon foundries) is gaining momentum the world over. The country plans to set up a chain of design centres. Fabrication of chips on the designs from these centres will be done in silicon foundries abroad till a provision is made in the country. It is expected that SCL and BEL would start functioning as silicon foundries in the near future.

Manual mask making facilities exist in many organisations in the country. The current capability in the country in mask fabrication is based on pattern generator and photorepeater which have been in regular use at BEL, Bangalore, for several years now and lately at CEERI, Pilani. Both the organisations have CAD facilities as well which generate the mask drawings on magtapes. These serve as the input to the pattern generator which generate the pattern on a high resolution glass plate for making working masks.

The country has competence to process wafers up to 7.5 microns and comprehensive facilities exist at several organisations in industry R&D and academic sector. The equipment at these organisations has been in general suited to the processing of wafers of maximum diameter of 2″ only. This capability can be raised to 3″ diameter without significant additional investment. Some of the research organisations have a few advanced equipment like ion implantation system, dry etching, vacuum sputtering and electron beam metallisation which are in regular use.

The wafer fabrication facility at SCL is fairly contemporary and would process wafers of 4″ diameter although most of the equipment is capable of handling 5″ diameter wafers. The facility would provide feature size of 5 microns to begin with and is expected to progress to 3 microns by 1987-88.

About a dozen organisations in the country have facilities for fabricating hybrid microcircuits (HMCs) primarily for in-house use. The more notable among them are BEL and ITI in the production sector and CEERI in the R & D sector which besides meeting their internal needs have also fabricated HMCs for other users.

BEL and ITI have been regularly producing HMCs for the last few years. While BEL has produced hybrids for several application areas, e.g., audio frequency amplifiers, radio frequency amplifiers, resistor networks and filters, ITI has mostly concentrated on communication circuits. Another public sector company, Electronics Corporation of India Ltd. Hyderabad, has a modest facility for simple circuits. However, it has already taken action to augment the facility with advanced equipment.

CEERI has developed capability of fabricating circuits of high complexity. Some of the HMCs developed by it include TV tuner, click suppressor circuit for use in telephone, specific circuits for telemetry and voltage controlled oscillator.

Oceanography

AFTER ENTERING into the nuclear and space clubs India is now poised to become the first developing country to break the big power monopoly in deep sea mining.

Seven years ago scientists of the National Institute of Oceanography (NIO) in Goa brought up manganese nodules from depths of 5,400 metres in the Indian Ocean. They found a huge carpet of polymetallic nodules within a four-day sailing from the mainland and only about a day's sailing from the Indian island of Minicoy. Since 1981 they have recovered more than 50 tonnes of nodules in many explorations and surveys in the central Indian Ocean. With this, India has joined the USA, the UK, the USSR, Japan and West Germany, that have so far collected nodules from the seabed.

India's entry into the ocean club was made possible by its first and only research ship 'R V Gaveshani'. Originally a hopper barge, it was redesigned and converted into a research vessel seven years ago by the Garden Reach Workshop in Calcutta at a cost of 3 million dollars. It was given to NIO, one of the 40 institutes under the Council of Scientific and Industrial Research (CSIR).

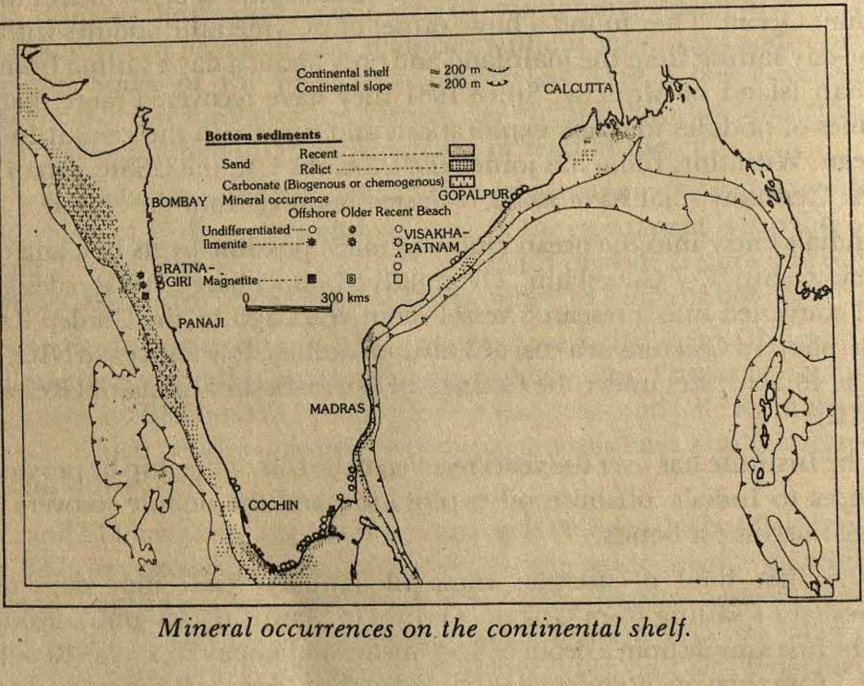
The Institute has over the years recovered the cost of the ship by providing services to India's offshore oil exploration and the nodule recovery has indeed become a bonus.

The first haul of nodules came in January 1981, nine days after Gaveshani's sailing from Goa on a cruise to Mauritius. Its grab—brought up the first sample from a depth of 3,600 metres on January 26, India's Republic Day. From then on, nodules were hauled up from several locations at depths ranging from 3,600 to 6,000 m, Gaveshani's survey also revealed the presence of nodules in the exclusive economic zone of Mauritius.

The country had been preparing for the nodule hunt since 1977. A deep echo-sounder, dredgers and a 10,000 m winch, underwater cameras for stereo photography, 22 'boomerang grabs' and several other equipment were added to Gaveshani. The greyish-black nodules picked up by Gaveshani ranged in size 9 to 8.5 cm and 200 gm in weight. Their concentration varied from one to five kg per sq. m. which is considered economical for mining. Indian Ocean nodules are known to have a maximum of 37 per cent manganese, 37 per cent iron, 1.55 per cent nickel, 1.6 per cent copper and 0.99 per cent cobalt. NIO scientists say their samples may contain traces of gold also.

Encouraged by its success in its maiden attempts, NIO made two more cruises later to the nodule-rich central Indian Ocean. Although,at present, India is not ready for commercial mining, indications are that a seabed mining agency similar to its offshore Oil Corporation may be set up in the near future.

Of late, India has given high importance to oceanographic research. The government in 1982 had set up a Department of Ocean Development (DOD) under the Prime Minister which is now to take on complex missions like the deep sea mining.



Mineral occurrences on the continental shelf.

The principal objectives of the ocean development programme launched by the DOD are exploration and exploitation of various ocean resources such as food, chemicals, minerals transportation, recreation and energy—and to improve socio-economic conditions of the vast population.

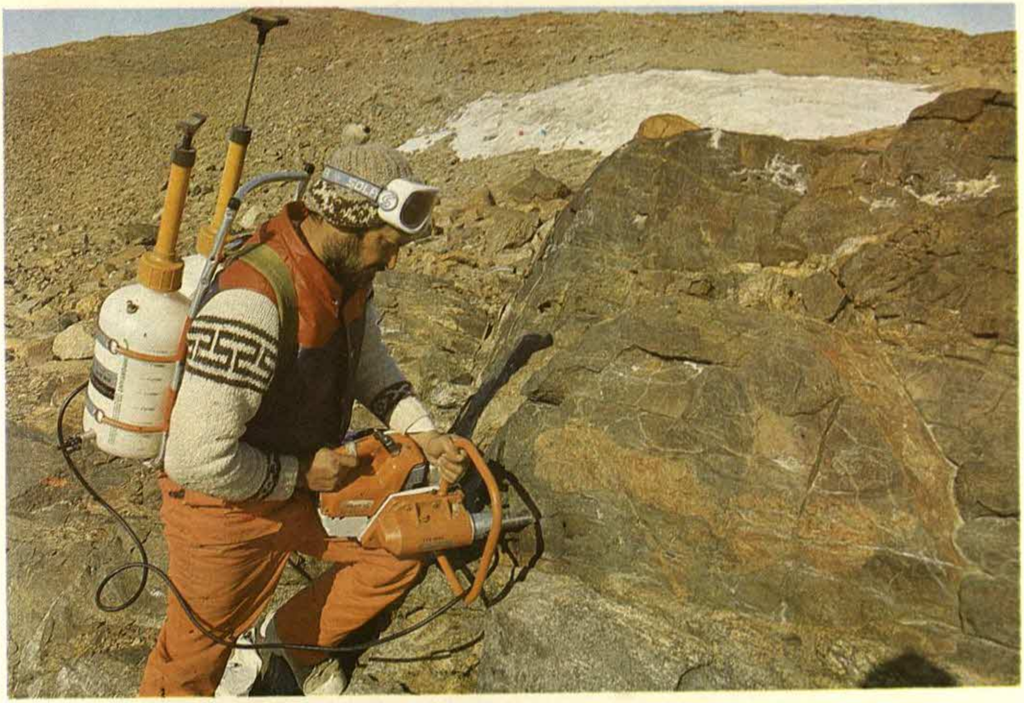
The scientists at the Regional Research Laboratory, Bhubaneshwar, have

Mounting of Satcom Dome at Dakshin Gangotri in Antarctica

Penguines in Antarctica

Naval Helicopter Getting Ready for Operation

Indian Communication Link at Antarctica



Geological Survey in Schirmacher Region

A View of Gaveshani

A Naval Helicopter at the Indian Permanent Station—Dakshin Gangotri

A Snow Vehicle Busy at Work

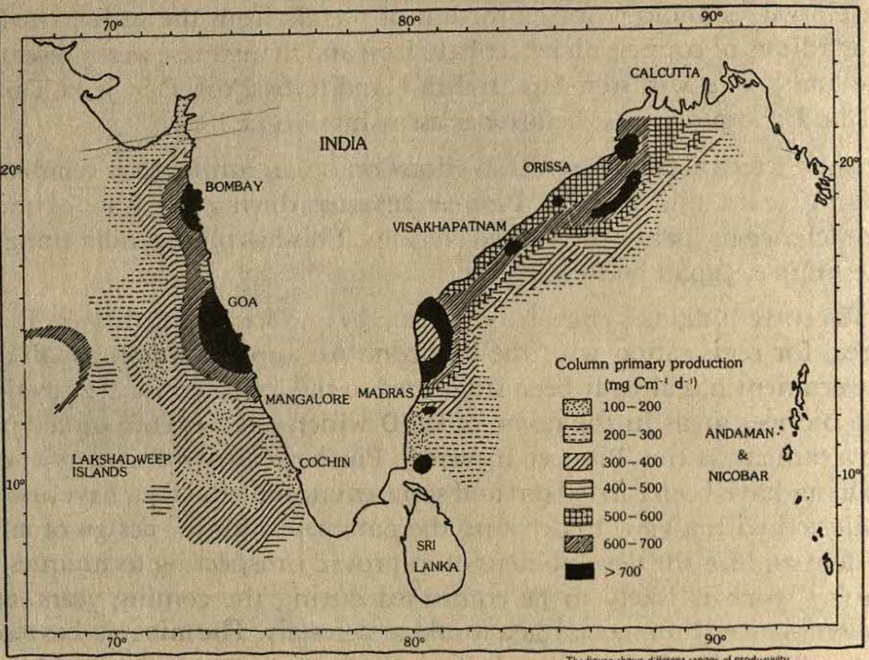
developed technology for extraction of metals from the seabed nodules. Madallions of copper, nickel, cobalt, iron and manganese were presented to the late Prime Minister, Mrs. Indira Gandhi, by Prof. P.S. Jena, Director of the Laboratory, just before her assassination in 1984.

India's technical and research efforts on ocean mining have enabled the country earn the status of Pioneer Investor during the Law of the Sea Conference in 1982 at the United Nations. This has placed India along with the France, Japan and the USSR.

Recently India has completed the survey and located a suitable 'Pioneer Area' for registration with the Prepcom. An application on behalf of the government has already been submitted to the Prepcom for registration of the pioneer areas in the name of DOD which has been appointed by the government as the 'Pioneer Investor'. Further extensive surveys at closer spacing have been carried out and some environmental data have also been collected with a view to defining the parameters for the design of mining system and for the development of improved prospecting techniques. The survey work is likely to be continued during the coming years, as the collection of environmental data would be necessary. The mine site has recently been allotted by the Prepcom. India is the first country in the world to have the registration of the mining site completed. The mining site is in the central Indian Ocean and it has an area of 150,000 square kilometres. The country has been registered by the United Nations as a 'Pioneer Investor' for deep seabed mining which gives it the exclusive right of exploring up to 1.5 lakh sq. km. in the Indian Ocean.

Exploration and exploitation of polymetallic nodules in the deep sea require development of submersible technology with ultimate capability to explore up to 6,000 m depth. This is inescapable for providing support and to conduct on-the-spot inspection and repair work for collection and mining system. Such a craft (submersible) would also be useful for visually verifying results of all surveys of sea bottom made from ocean surface and to provide a pilot guidance and to assist in the deep seabed mining system. The DOD, therefore, plans to acquire a complete design, fabrication and operation of submersible. Action has already been initiated to acquire one submersible to be manufactured abroad with full participation of Indian engineers in its design and fabrication and to manufacture the second submersible in the country with our trained engineers under the overall guidance and supervision of the collaborating agency. As per the plans envisaged, the first submersible should be available in the country within the next few years.

This development will accelerate the preparatory work connected with deep sea mining. However, the technology for carrying out deep sea mining



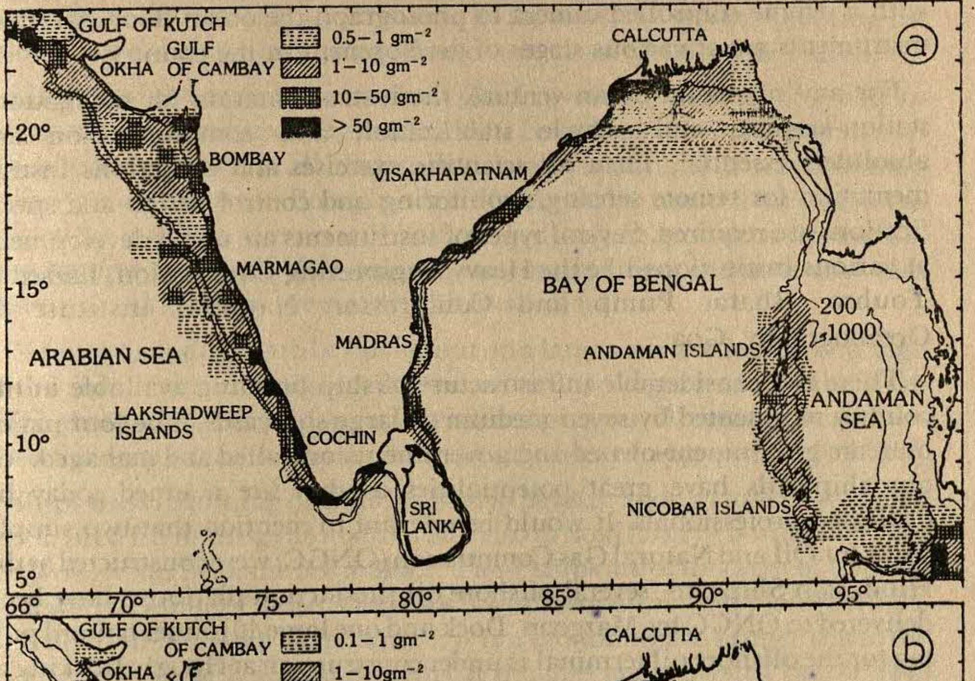
The figure shows different ranges of productivity

Column primary production.

is today only available in a very few countries. No country or any mining company has yet demonstrated a properly evaluated and economically viable system for mining of polymetallic nodules. However, it is expected that by 1995 commercial exploitation of polymetallic nodules will start in the country and abroad.

A variety of instruments are used during mining operations. In any prospecting programme, the position of ship should be very accurately fixed. This process helps in demarcating manganese—nodules on the ocean floor. Even while the ship is drifted, it should be able to record its position accurately as it is likely that the ship may have to return to the same position for further exploration. Satellite navigation and omega position fixing from the land serve as a check to determine the exact position of the mining ship at each sampling location.

A deep sea echo-sounder and a seismic profiler give the exact depth and the type of the ocean floor. A hydrocast gives the information about temperature, salinity, heavy metals, nutrients, oxygen from the sea which are collected from different depths of the sampling station. The wave recorder measures the wave heights. Bathy thermograph is used to measure thermal structure in the upper layers. The nodules are collected using different types of samplers. These samplers are sent to the bottom of the ocean floor, where they collect the nodules and bring them to the surface.



Distribution of (a) macrobenthic and (b) melobenthic biomass in the Indian seas.

These graphs can be used at depth even greater than five km. The boomerang grab is also an important instrument for collecting manganese nodules. It goes to the bottom, collects nodules from the ocean floor, discards its weight and then returns to the surface. The grabs are then detected and brought to the ship. The boomerang grabs can also be fitted with a remote controlled camera to photograph the ocean floor. All these instruments are at various stages of development in the country.

For any successful ocean venture, the instrumentation for navigation, station-keeping and vehicle stabilization and communication are absolutely essential. Then for scientific exercises and operations instrumentation for remote sensing, monitoring and control design and specifications are required. Several types of instruments are under development at various institutions like the Heavy Engineering Corporation, Larsen & Toubro, Bharat Pump and Compressor, National Institute of Oceanography, Goa.

There is a considerable infrastructure of ship building available in the country represented by seven medium to large shipyards. The four major ones are government-owned and government controlled and managed. All our shipyards have great potentialities as they are manned today by dedicated professionals. It would be relevant to mention that two supply ships for Oil and Natural Gas Commission (ONGC) were constructed at the Hindustan Shipyard, several offshore oil production platforms have been delivered to ONGC by Mazgoan Dock and one large 40 tonnes bollard pull tag for the offshore oil terminal is under construction at Hoogly Docking at Calcutta.

Several methods based on dredging techniques have been used to mine the nodules from deep sea. Three methods are known to be economically important. These are: 1. hydraulic system 2. air-lift system and 3. continuous line and bucket system.

In addition, the dredges have bucket ladders, draglines, clamshells with the dredging system.

In the hydraulic lift system, the two collecting heads suck manganese nodules and bring them up to the ship. The entire system works like a vacuum cleaner in the water.

The air-lift system consists of a long pipe which comes from the ship and goes down to the ocean floor. The pipe is connected with a head to collect manganese nodules from the ocean floor. The nodules from the seabed pass to the bottom of the pipe where air with pressure force nodules to go upwards and finally get deposited on board the ship. Two or more ships can be used by any system to transport the collected nodules to the shore.

The third method, known as the continuous line bucket system, is also useful because it is simple, cheaper and efficient. The system consists of a long loop of cable with buckets attached to it, at intervals of about 25 m. The long cable moves down to the ocean floor bringing the buckets in contact with the ocean floor from where the nodules are scooped up. On their return, the nodules are dumped into the ship. In this way, the system can bring the nodules to the ship without causing much disturbance at the seabed.

Mining of the nodules from the seabed involves a number of problems which are to be assessed very carefully. In large scale mining, water masses are likely to move in all directions thereby stirring and redistributing sediments on the ocean floor. It is felt that the stable ocean floor which has existed for millions of years will be disturbed and the growth of the nodules may become impaired after carrying out mining operations. It may also destroy the organisms present on the ocean floor.

Mining of nodules is to be carried out on a large scale and hence the design of the ship and the dredging system are to be so organised that these can mine about four million tonnes of nodules per year. Bringing the nodules from the deep sea to the surface requires a power of approximately 4 MW.

Ships used in mining operations should be large enough to accommodate pipes, used for mining the nodules and also to hold large deposits, after they are brought up from the ocean floor. These ships are of the order of 1,50,000 dead weight tonne or more. The ships have to remain at sea for long periods, even up to three to tour years, since it is not economical to bring them to the shore quite often. It would be better if nodules are processed on the ship itself as it would make the whole operation economical.

Potable Water from the Sea

In terms of population growth, the world supply of fresh water is dwindling very rapidly every year, and therefore, measures are being undertaken to obtain drinking water at least from all possible sources. There are many areas in India where potable water is in short supply and thus people even resort to drinking saline water, very often containing fluorine which causes what is commonly known as "Fluorosis"—a disease leading to painful symptoms of bone deformity. The following desalination technologies are being employed to generate fresh water from sea-water.

Solar stills are well suited for small and isolated communities where water is limited and power is either not available or is in short supply and the transport of large quantities of water from neighbouring places is not practicable. Solar stills are ideal for small coastal villages as they run on a non-expandable energy source. They are simple to construct and their operating and maintenance costs are minimal. A solar still of 5,000 litres per day capacity has been installed in Avina village in Gujarat where 500 families obtain their drinking water from this source.

In Flash Distillation, heated saline water is allowed to flow through a series of chambers which are maintained at different pressure below atmospheric, and progressively decrease towards the end of the series, saline water thus evaporates in each section of the chamber, the vapour is released and then condensed over a bundle of tubes cooled by circulating sea-water inside them. Distillate of fresh water produced at each stage is gathered either separately or collectively to be used as fresh water.

Electrodialysis employs ion-selective membranes for the desalination of brackish water. Electrodialysis is more economical for salinities below 5,020 p.p.m. The energy cost of the process is directly proportional to the salinity, thus beyond 5,000 p.p.m., the process is no longer economical.

Reverse Osmosis is the most widely used desalination technique. In this process, suitable osmotic membranes are used which reject salts and allow the water to pass through. Several plants with capacities of 10,000 to 15,000 litres have been set up in Indian villages to provide potable water to the villagers. A few years ago, two desalination plants of 50,000 litre capacity per day have been established, one in Tamil Nadu and the other in Andhra Pradesh.

In the future, desalination technology of different types will play a distinct role, particularly in India's rural development programme, for the supply of potable water. However, it is not certain that desalination technology can produce enough water to meet the demand of a growing population. It can only supplement other technologies but will not provide a substitute.

Marine Products

In India the utilization of marine plants and animals as a raw material for effective and safe drugs and pharmaceuticals is of recent origin. Of the 100 or more marine organisms that have been screened so far, 42 have given promising results. The most remarkable feature is the anti-fertility properties of ten marine organisms. Recently prostaglandins, which play a major role in controlling biological reproduction have been isolated from the seaweed *Gracilaria sp.* by Australian researchers. Studies in India indicated that all those species of marine algae that exibit antifertility properties may also contain prostaglandins. Research in this field and also on the cultures of marine bacteria, fungi, yeast, etc., will advance considerably during the next two decades for the production of bioactive substances.

Of the sixty elements present in sea-water, only six are recovered commercially. These are sodium and chlorine in the form of its compound, bromine, calcium and sulphur in the form of calcium sulphate (gypsum). Owing to its low concentration, the recovery of potassium directly from sea-water is not considered economical. However, it is possible to recover potassium from bitterns (the mother liquor from salt extraction). Efforts are being made to recover many useful elements commercially, namely, iodine, uranium and gold from sea-water.

So far, owing to the availability of cheapter extraction methods from land deposits, the technology of obtaining some of these valuable elements either from sea-water, sea-brine or seaweeds is not economical. Recently a commercial process for the recovery of uranium from sea-water has been reported. It is almost certain that research in this field will accelerate considerably and a very large number of elements will be recovered from sea-water in commercial quantities by the year 2000.

Chemically stable minerals are not decomposed by weathering processes, and as rocks surrounding such minerals become dissolved and disintegrate, the heavy particles settle at the bottom in layers and become continuously enriched as heavy, chemically stable minerals. All such concentrates are called placers. Mineral placers along the seashores, usually known as black sand, occur in many localities along the Indian coast. Deposits on the west coast are largely concentrated as high-grade beach and low-grade dune deposits, extending from Kanya Kumari to the Maharashtra coast with interruptions in between. These deposits mainly contain ilmenite, rutile, zircon and monazite with varying proportions of magnetite and garnet.

Mineral placers are also reported on the coastal tracks of many countries in the world. However, economically exploitable deposits are known only from the beaches and the shelf of Australia and India (rutile, zircon), India and Brazil (monazite and ilmenite), Norway and Japan (magnetite), Malaysia (wolframite and cassiterite), South Africa (chromite and precious diamonds), Alaska, Canada, USSR and South Africa (native gold and platinum), the USSR and United States (ilmenite and rutile). Apart from these major occurrences of placer deposits, minor deposits have also been found off Mozambique, Senegal, Indonesia, the Korean peninsula, Thailand and Sri Lanka. As time passes, their importance and value will go on increasing and by the turn of the century they will probably be exploited extensively.

Mining from the sea is either by tunnelling, pumping or dredging. Mining companies are extracting coal from the sea beneath the shelf in several countries by tunnelling under the sea for more than five kilometers. Iron ore is also extracted by tunnelling. However, undersea tunnelling for minerals is expensive and sometimes hazardous. Special engineering problems of undersea tunnelling add to the extraction costs, making competition with land producers totally uneconomical. Pumping of many minerals from the seabed is also an increasing activity, as in the case of sulphur and potash in many countries. Thus many offshore and placer deposits are exploited by pumping the material from the seabed to the shore. Dredging in the sea is becoming increasingly important for mining of heavy minerals such as aragonite and biogenic material (corals, shells etc.).

By the turn of the century the demand for almost all minerals will increase two- or threefold. Thus their production from land sources alone will be difficult to meet the rising demand. In India, efforts are on to collect all possible information on the nature of marine mineral resources to work out the most efficient extraction methods of both placers and offshore deposits so that the withdrawal of minerals from the seabed can become economical. It is hoped that environmental protection will not be ignored in search of profitability.

Antarctica Expedition

Research by Indian scientists in the frozen continent of Antarctica is expected to be intensified in the next few years following the successful establishment of air and communication link between the Indian mainland and "Dakshin Gangotri", the country's permanently manned station. This makes India one of the few countries in the world which have set up permanent stations and can operate them round the year.

Antarctica, the windiest, coldest and stormiest of all the continents, is attracting world-wide attention because of the biological bounty teeming in its surrounding seas and the likelihood of vast oil and gas reserves and other mineral deposits on its continental shelf. The activities on the continent are overseen under the terms created by the Antarctica Treaty signed in 1959 by 12 nations.

The entire land area of Antarctica is almost without life but its seas are among the most biologically productive eco-system in the world. Seals are usually found on the ice pack and sometimes they haul themselves out on the beaches. More than 40 species of sea birds are known to breed here, many of them near the sea coast. Springtails, mites, lice and midges, microscopic soil fungi and algae, lichens and mosses; and the mainland of Antarctica has only a few native higher plants, which are grasses. Penguins are the natives of Antarctica.

Krill of the Antarctic sea is one of the most famous living resources of the world. It is estimated that the amount of krill present in Antarctica must be around 1,000 million metric tonnes, of which 40 to 50 million tonnes can be harvested annually without endangering the stock. The Antarctic ice-cap contains 70 per cent of the world's store of fresh water and more than 90 per cent of the world's ice. Almost 1.4 trillion tonnes of ice breaks off annually and melts in the Southern Ocean.

In July 1981, the Government of India decided that it would be very important from scientific point of view to send and expedition to Antarctica as it would add to our knowledge of the various features related to the Indian Ocean and also of the weather phenomenon related to the monsoon. Antarctica is crucial to the global weather phenomena such as the air circulation patterns, the cold phases and the sea currents. It therefore invites a study of its physical parameters like the radiation and water balances.

Indian science has now attained enough maturity and expertise in various branches of geology, geophysics, oceanography, meteorology, astrophysics, space science and communication science to take up a detailed scientific study on the landmass of Antarctica and of the oceanographic features in the surrounding seas. Keeping this in view, the Department of Ocean Development organised seven scientific expeditions to the south Indian Ocean and Antarctica and the eighth one is expected to leave for the continent in November 1988.

The first expedition, code named "Operation Gangotri", was undertaken with a 21-member team of enterprising Indian scientists, technicians, and navy personnel on December 6, 1981, and was headed by Dr. S.Z. Qasim, now Secretary of the Department of Ocean Development. The expedition which was purely exploratory in nature, set foot on Antarctica on January 9, 1982, and returned on February 21, after a stay of ten days.

After the successful completion of the first expedition, a second expedition with a 28-member team led by Mr. V.K. Raina of the Geological Survey of India, landed on Antarctica on December 28, 1982. The team stayed in Antarctica for nearly two months and carried out studies on several scientific disciplines. The team also identified a site for our permanent station. The third expedition left India on December 1, 1983, under the leadership of Dr. H.K. Gupta and constructed the permanent scientific station on "Dakshin Gangotri". The permanent station consists of prefabricated structure. It is specially designed for the Antarctica conditions and can withstand winds up to 100 knots. The double storied blocks, with sloping roofs, are connected by a single storeyed corridor. The structure rests on a raft foundation. The building is totally self-contained and includes workshop, laboratories surgical room, toilets, a communications room, living quarters, recreation facilities and library facilities. It is also provided with an ice melting plant and the entire waste materials are chemically treated and disposed of safely without affecting the Antarctic environment. The superstructure was ready by the end of January 1984. The third expedition team included two women scientists.

The most important feature of the third expedition was that a wintering team of 12 Indians under the leadership of Col. S.S. Sharma stayed on in Antarctica for the first time during the Antarctic winter.

The 83-member team of the fourth expedition sailed from Goa on December 4, 1984, under the leadership of Dr. B.P. Bhattacharya, Director, Indian School of Mines, Dhanbad. They carried out surveys and experiments to identify the minerals potential of the area, established a direct high frequency communication link between India and Antarctica. They also carried out maintenance of the permanent Indian Antarctica station and constructed additional accommodation and laboratory space. Besides, they erected a large garrage for parking of vehicles and storage of equipment, and built a small fields station at the Schimacher Hills which is about 60 kilometers away from Dakshin Gangotri.

After the successful completion of the fourth expedition, the Government of India launched the fifth one with an 88-member team on November 30, 1985, under the leadership of Mr. M.K. Kaul of Geological Survey of India, which landed on Antarctica on December 24, 1985. The expedition team consisted of 21 scientists drawn from 12 different institutions including two women. The logistic component consisted of 67 persons from the three services. The team returned home in March 1986 with a wealth of information and material, which are likely to throw a new light on meteorites, climatic conditions and birds of the icy continent. The seventh expedition has also accomplished its assigned task, and its wintering team is still on the icy continent.

A comparison of Antarctica with the other continents of the world indicates that there may exist more than 900 major mineral deposits in the Antarctic region. It is expected that about 20 mineral deposits may be located in the ice-free area. It probably contains the world's biggest coal field, but under present conditions it is not considered economical to mine some of the minerals.

So far 16 nations have carried out extensive scientific research in Antarctica and seven have made territorial claims on it. Recent geological surveys have aroused the interest of several nations on the reported occurrence of large mineral deposits particularly of oil and gas.

The Government of India has allocated Rs. 45 crore for the Antarctic programme during the Seventh Five-Year Plan (1985-90). The programme for the next five years includes aerial surveys of the entire glacial and mountain regions of Queen Mand Land for its geology, geophysics, biology and oceanography of the adjoining sea. In addition, investigations on krill would be carried out. Highlights of 1987-88 programme will be the exploration and site selection for the establishment of a second manned station in the Antarctica, strengthening of communication links, and establishment of Antarctic Study Centre in India. The highlights of the 1988-89 programme will be site selection for more manned station, setting up of observatories and laboratory facilities and development of technology for using krill as human food.

Non-Conventional Sources of Energy

INDIA HAS brought the sun down to earth to put cheer into remote villages by providing them water and power. The idea of the strides India has taken in harnessing the solar energy could be guaged from the fact that a variety of systems have been developed ranging from supply of drinking water to providing sophisticated power pack to the first Indian scientific expedition team to Antarctica.

The thurst of the research efforts in the country in the solar energy has been directed both towards solar thermal applications and direct conservation of solar electricity. Utilisation of solar energy is of great importance to India since it lies in a tropical climatic region where sunlight is abundant for a major part of the year.

Until 1979 activity in the field of solar photovoltaic in India was concentrated only on research in solar cells in a few national laboratories. Developmental activity was directed only towards laboratory scale solar cells fabrication, mainly for the space programme. In late 1979, the government initiated a national programme of research development and demonstration of solar photovoltaic energy sources. The area of interest was gradually expanded from solar cells along to solar photovoltaics and from purely scientific research to technological and engineering activities. An integrated approach was evolved for research development, manufacture, deployment, demonstration, education and training with the active participation of a public sector electronics company and various national research laboratories and academic institutions. Whereas scientific research on solar cells and materials was fully supported in the academic institutions, the product development activity was given priority in the public sector company.

In the sixth plan, a significant increase in the allocation and activities has been noticed in the areas of new and renewable sources of energy. A large number of applications of solar thermal conversion both for urban and rural areas have been sponsored by Commission for Additional Sources of Energy (CASE) in this area. Two types of solar collectors have been developed and know-how has been passed on to the industry. A solar energy boosted heat pump suitable for generating refrigeration effect has been developed. Under the demonstration and field trial programme in this area, systems like water heaters and dryers, wood seasoning systems and pumps are being installed. Several methods/models of solar cookers including simple hot box type solar cookers with one reflector, solar oven with multiple reflectors, and solar concentrators have been developed.

The most promising and fast moving solar technology today is that of solar cells, flat metallic blue chips made of highly pure silicon that can convert sunlight into electricity. Though silicon is available in abundance in every country of the world the process of refining the silicon to more than 99.9 per cent purity is extremely complex and its cost is extremely high. This makes solar cells 10 to 15 times more expensive than ordinary ones. The heart of a photovoltaic system is the so-called solar cell which is usually manufactured from a monocrystalline water of high purity silicon. Solar cells have also been made from polycrystalline silicon wafers as also amorphous silicon films. The cells are connected in series or parallel combinations to give the desired voltage and current ratings and encapsulated to form modules. The modules are interconnected to form panels and arryas to deliver the required power for any application. The advantages of photovoltaic (PV) technology such as the ease of operation, reliability, minimum maintenance due to lack of moving parts, have been widely recognised. PV systems are thus suitable for installation in rural areas and isolated locations for a variety of applications such as water pumping for microirrigation and drinking water supply, community and street lighting, power supplies for microwave repeater station, communications equipment, radio and TV receivers.

Work on photovoltaic technology development in the country began in the fifth plan. Several R&D projects were undertaken at national laboratories and IITs. A major project on low cost solar cell technology was carried out at the Central Electronics Ltd., which was treated as the lead organisation in the country for PV development At the start of the sixth plan, the basic technology for solar cell and module manufacture had been developed and a few systems designed for terrestrial application. Based on these developments a programme comprising of pilot scale production and demonstration and intensive R&D was taken up during the sixth plan.

Researchers in leading laboratories and universities are trying to achieve self-reliance in this vital high technology area which is essentially based on the traditional and mature semiconductor process industry. There are four basic areas of activity in the development of the engineering and technology of solar photovoltaic system which include development of basic raw material, particularly silicon; solar cells and modules balance of system components and complete system engineering.

The Department of Non-Conventional Energy Sources (DNES) has the responsibility for the development, production and application of solar photovoltaic devices. This route of solar energy utilisation is attractive in view of the favourable solar radiation conditions and large requirement for electrical energy for decentralised application. The ease of installation and maintenance lack of noise and pollution, and long life make photovoltaic systems ideally suited for use in remote and isolated areas, forest, hilly and desert regions.

The technology so far developed relates mainly to the processing of single crystal silicon wafers into solar cells and their design and development for different application. Several improvements and newer techniques in cell and module fabrication have been introduced in production. These include screen printing of front and back contacts, polishing and texturisation, testing and encapsulation leading to reduction the cost of production. Silver paster for screen printing has been developed by CEL. Meanwhile, another public sector undertaking, Bharat Heavy Electricals Ltd. (BHEL), has launched a production programme based on in-house technology. Average cell efficiencies ranging between 10 and 11% have been achieved at BHEL and CEL using CZ wafers. Some experimental work using semicrystalline wafers is also in progress. The hand on experience gained should enable the country to acquire and adapt technology and equipment needed to further upscale the production.

In National Physical Laboratory, scientists have developed technology for fabrication of thin cadmium sulphide and copper sulphide ($CdS : Cu S$) solar cells. These cells are formed over an ordinary window glass substrate in which semiconducting layers in polycrystalline form are built up using vacuum deposition and chemical process. These are totally encapsulated to withstand the climatic changes. To evaluate the reproductibility of the technology and the control over process variables a laboratory level batch production facility has been established. Several hundreds of cells have been fabricated having conversion efficiency in the range of 5-6%. These cells have shown remarkable stability over a number of years.

The NPL has also established facilities for testing the thermal performance of solar collector. Facilities have also been established to test the thermal performance of solar collectors including a comparative testing of a collector with reference to a standard collecting. Besides measuring experimentally the efficiency of a collector, facilities exist for determining the physical parameters such as the refractive index and absorption coefficient of the glaxing, thermal conductivity of back and edge insulation. Using these and knowing the design parameters, the theoretical efficiency could be determined.

During the sixth plan, the DNES implemented a comprehensive programme of R&D pilot production and demonstration relating to PV technology. The programme led to development of indigenous technology for production, creation of initial infrastructure for the manufacture, installation and maintenance of PV systems and promotes awareness among potential users.

An indigenous plant to produce pure silicon was commissioned at Mettur in Tamil Nadu in 1986. The plant envisages annual production 25 tonnes of polycrystalline silicon and conversion of part of it into single crystal ingots and wafers—the backbone for a host of electronics devices and solar cells that convert sunlight into electricity.

The indigenous process uses high pure silicon tetrachloride (STC) as raw material. It is reacted with hydrogen gas which reduces STC into metallic silicon that gets deposited on a U-shaped heated tungsten filament inside a double shell reactor. The silicon produced at the plant costs between Rs. 750 and 850 per kilogram which compares with imported silicon. The silicon project is the outcome of a unique 15-year collaboration between Mettur Chemicals and two scientists of the Indian Institute of Science—Prof. C. Suryan, a physical, and Prof. A.R. Vasudeva Murthy, a reputed chemist considered to be the father of silicon industry in India.

An integrated programme on amorphous silicon cells made steady progress. Plasma deposition facilities for experimental work have been established at the Indian Association for Cultivation of Science, Calcutta, Indian Institute of Technology, Delhi, and University of Poona. Silane gas, which is an essential input to amorphous silicon production, has been produced in small quantities at IIT, Kharagpur, and IIS, Bangalore, and is being tested for its quality.

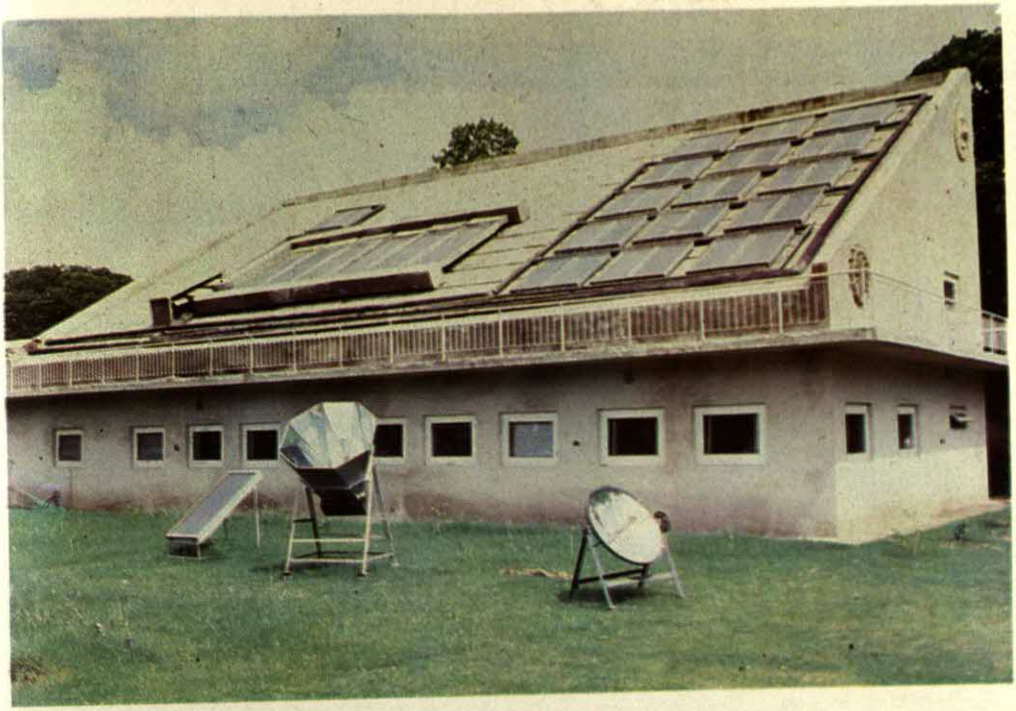
Research on the other aspects of PV technology such as photoelectrochemical solar cells, thin film devices based on compound semiconductor materials such as copper indium diselenide, on implantation and laser annealing systems development continued in several institutions. The DNES is making efforts to promote and evaluate indigenously produced silicon to assess its suitability for PV production. Solar cells and modules made from such materials have been found to be comparable in performance to devices made from imported silicon.

At the Indian Institute of Technology in Kharagpur, researchers are working on ways to change the farm waste into a high-tech energy product. They have found that rice husks contain about 18% silica—commonly known as white ash. The researchers are now working on a cheaper way of reducing silica to fine grain silicon. They hope to use recyclable aluminium in the reduction process and polycrystalline ingots ready for use in solar cells.

There are at present two programmes in operation for production of solar cells and modules in the country. The first of these at the Central Electronics Ltd. and another at BHEL where a production capacity of 1 MW have been installed.

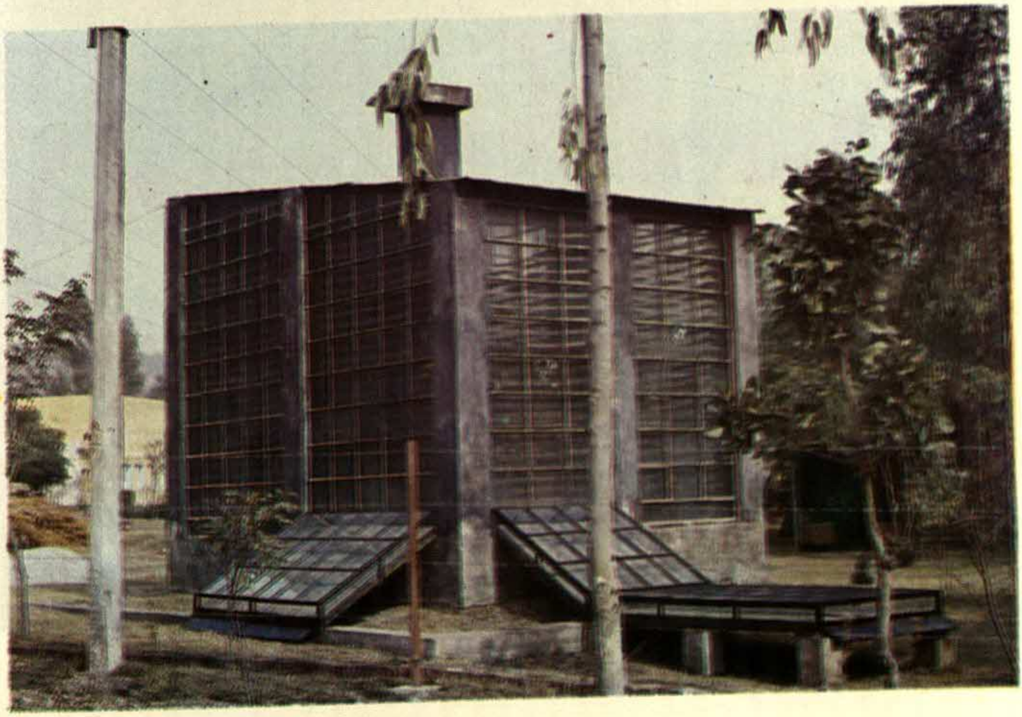
A five year National Solar Photovoltaic Energy Demonstration (NASPED) Programme was initiated at CEL in October 1980 with an outlay of Rs. 11.97 crore. The programme, which was approved by CASE in May 1981, envisages the establishment of pilot scale production facilities at the level of 1 MW by end of this year, the development of PV systems for a variety of application and the demonstration/development of these systems for purposes of field trials, evaluation and popularisation. The programme sought to upscale the existing production capability and demonstrate the viability of PV energy in Indian conditions.

There are at present two programmes in operation for the production of solar cells and modules in the country. The first of these at Central Electronics Ltd., where a production capacity of 600 KW per year have been installed by the end of March 1984. The actual production under NASPED has been behind the schedule by over six months during the last 2 to 3 years. As against a target of 150 KW for 1983-84, the actual production at CEL is likely to be around 115 KW. A target of 400 KW is being envisaged for 1984-85, which was the figure originally set for the period September 1983 to October 1984. Among the reasons for shortfall in production have been difficulties and delays in developing newer process techniques and applying them for production, shortages of certain raw materials, disruption due to shifting of operations to a new building. Acute shortage of silicon wafers has hampered the production in 1983-84. Two factors have contributed to this shortage, firstly, a shortage of pure silicon in the world market, and secondly, import of silicon wafers required licences under automatic and supplementary licence procedures as per the import policy for 1983-84. Based on the total experience with NASPED so far, vigorous efforts will be required to achieve the targeted production level of 1 MW by September 1988. The second production programme is being implemented at another public sector undertaking, BHEL, with a target of reaching 250 KW by 1988.

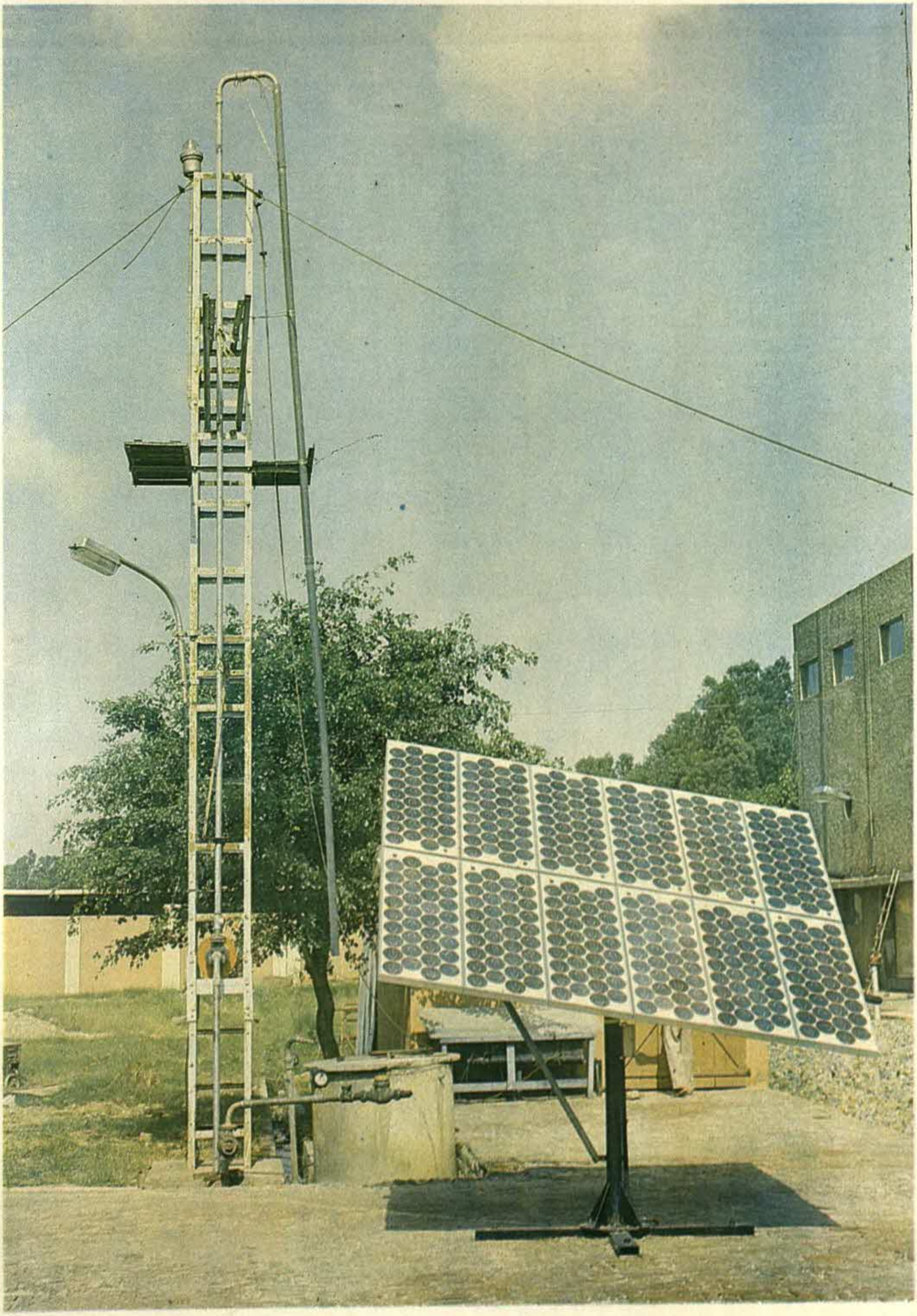


Solar Energy Panel at NPL, New Delhi

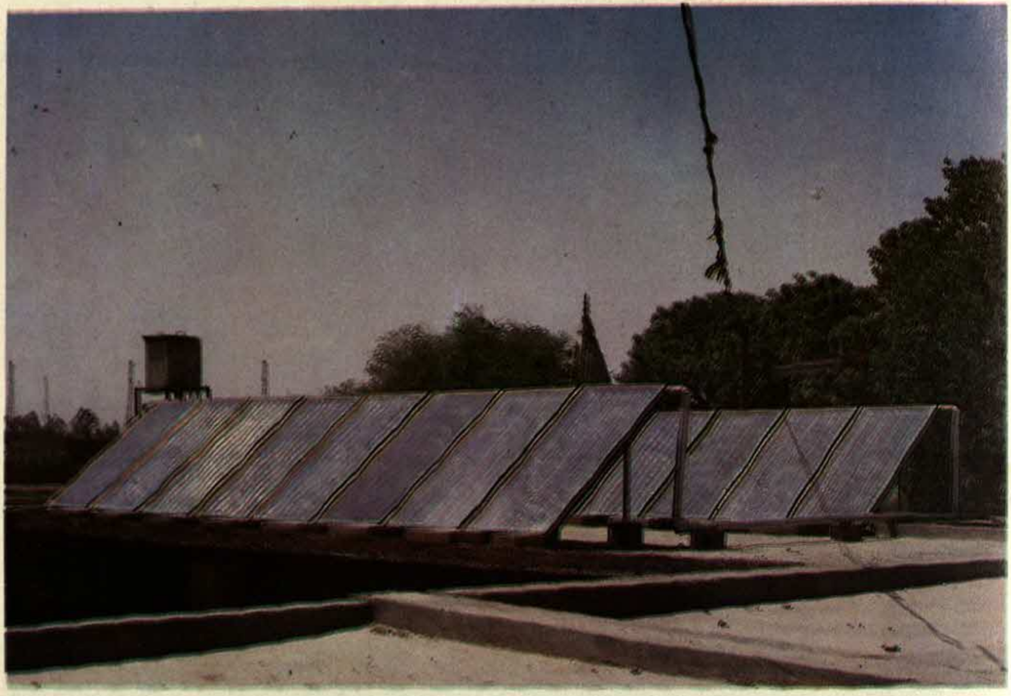
Solar Timber Seasoning Klin



Windmill



Photovoltaic System



Solar Water Heating System

Smokeless Chulha

About 40 R&D projects covering materials cell fabrication development of systems, concentrating newer types of cells have so far been funded by Department of Science and Technology and DNES. Detailed investigations have been made on the fabrication and evaluation of thin film solar cells including Cd S-Cu S cells. Work on extraction of silicon from rice husk and metallurgical grade silicon has been carried out with encouraging results. Technology for casting of polycrystalline ingots up to 50 mm diameter has been developed and efforts are being made to increase the size. Recently an integrated programme on amorphous silicon technology has been formulated and five projects, including two on saline preparation, have been sanctioned. Several projects in photoelectrochemical solar cells have also been funded by DNES.

There is a significant demonstration/field trial component in the NASPED programme. As part of this, water supplies for offshore platforms, community radio and TV sets, and street lights units have been developed and demonstrated in various parts of the country including Leh. Over 100 solar pumps and 50 other systems have been supplied by CEL. The pumps are being used for microirrigation, drinking water supply as well as training and demonstration purposes.

The first experiments is rural electrification using PV technology have begun recently. Salijipally in Andhra Pradesh became the country's first village to be electrified using solar photovoltaic systems. A 7.5 KW power supply system has been in operation since November 1983. Street lighting and other units are proposed to be installed in some tribal villages of Tamil Nadu soon. The feasibility of installing such systems in Jammu & Kashmir and Karnataka is being explored.

According to an official survey, the country has an excellent ocean thermal energy conversion (OTEC) potential and some of the best sites in the world are situated of the Indian mainland and near the islands Lakshadweep, Andaman and Nicobar. The total OTEC potential round India is estimated to be more than 50,000 MW which is about 153% of the present total installed power generation. A project is being launched by IIT, Madras, in collaboration with other national organisations.

There are other renewable sources such as hydro power, ocean energy, geothermal energy in all of which the country has programmes to succeed and for renewable sources of energy to make a significant impact in the country, it will be necessary not only to mount large scale programme sponsored by the government but also to involve the industry and voluntary agencies and other organisations in this task.

Funding by the central government for installation/use of solar thermal systems or device including community solar cookers varies from cent percent in case of its institution to 33.3 per cent in case of family type solar cookers. Solar photovoltaic water pumping systems and community lighting systems are being supplied at a subsidised price of Rs. 25,000 to state governments and other agencies. Some state governments and union territories are also giving subsidies on various solar devices.

Biogas

In a bid to provide a simple and cheap method of energy production, Indian scientists have developed a number of designs of biogas plants which make use of wide range of agricultural wastes like animal dung, human excreta, vegetable waste, water hyacinth and produce fuel in the form of gas, simultaneously with high quality manure.

About a dozen of designs, incorporating distinctive features either in the digester or gas holder have been developed in the country by various research institutes.

The research and development efforts in biogas have yielded useful results. Development of different designs of fixed dome biogas plant, development of ferrocement digesters, successful introduction to FRP to biogas technology and replacement of steel holders, rationalisation of biogas plant designs based on different agro-climatic conditions such as ambient temperature, resulting in reduced capital cost for construction of the plant, development of cheaper biogas plant designs which use lesser quantity of cement and masonry are some of the major achievements which deserves special mention.

Besides, the scientists have developed biogas plants which can operate on a variety of feed materials such as night soil, water hyacinth, agricultural wastes including banana stem, deoiled castor cakes, willow dust and food waste. Development of specialised and improved micro-biological cultures for biogas generation from deoiled castor cakes and other non-edible waste and residues, development of engines which can run on biogas alone (100 per cent biogas) and dual-fuel (20 per cent) diesel: 80 per cent biogas and successful integration of solar heating systems with biogas plants for improving gas generation during winter are among the other achievements.

There are four types of biogas digester designs: floating gasholder digester, fixed-dome digester, flexible bag digester, and experimental small and cheaper digesters, are in vogue today.

The floating gas-holder digester was the most popular digester design in the country in the early years of its introduction. Problems of corrosion and gas leakage and the high construction cost of the metallic gas-holder caused the collapse of its popularity. It is expected that the development of gas holder made of a cheap corrosion-free durable material may help regain the popularity of this design. For this reason the development of a cheap and good quality floating gas holder made of fibreglass may be further investigated.

The fixed-dome digester is the most popular design in India today. Its popularity is mainly due to its lower construction cost, local availability of the required building materials, its hidden underground structure, and the non-existence of the expensive floating metal gas holder with consequent reduction in maintenance costs. On the other hand, a plastered masonry dome is bound to develop cracks leading to gas leakage within a few years; and repair is a difficult job. To make this fixed-dome digester more effective, and scientists say the search for a cheap and appropriate lining to seal the inside of the dome should be intensified.

Very little data are available on the experience with the plastic bag digester in the country. However, flexible bag digesters appear to be very promising. Few operational problems, easy and cheap installation, high durability and stable gas pressure are its major advantage.

Smaller and cheaper digesters are expected to be more appropriate for the poorer groups. Moreover, the demand for smaller digester feed in these digester corresponds better with the mostly smaller quantity of cattle dung available with the villages. Portable digesters are also under development to overcome the immovable character of conventional digesters.

Experiments conducted at the National Environmental Engineering Research Institute have shown that cattle dung and water hyacinth, mixed in the ratios of 3 : 1 and 1 : 1 at an organic loading of 1.6 kg of volatile solids per cubic meters per day and a detention time of 30 days, can yield 30% more gas than with cattle dung alone.

It is a horizontal plant with a steel floating dome a vertical fed pipe at one end for easy feeding of the vegetable matter by pushing with a bamboo; a sloping roof and floor which helps the passage of light weight vegetable matter and its sludge towards the outlet; and a big outlet of suitable dimensions for easy disposal of partly decomposed sludge.

The Regional Research Laboratory, Jorhat, is now engaged in standardization so as to develop field-scale prototype digesters and optimum operation design. Two demonstration plants of 300 litres capacity having different dimensions and feed system were run for several months in the Central School premises of CMERI colony and in the institute's campus at Durgapur.

A system of using ferrocement precast segmental units for constructing digesters for biogas plants (3 to 8 meter cubic gas per day) has been developed and tested at the Structural Engineering Research Centre (SERC), Roorkee. The digesters are assembled with 4, 6 and 8 precast segments 15 to 18 mm thick. The wiremesh and wire reinforcement projecting on sides are used for connecting the segments when placed in a vertical position. The mesh laps from the joint ribs and also accommodate the inlet and outlet pipe junction with the digester wall. A rich cement-sand mortar is applied over the mesh joint areas and ribs are formed. Extra reinforcement could be provided in the joints and radial bands, projecting out at top, middle and bottom positions. The ferrocement (cement mortar reinforced with steel wiremesh layers) gas holders, designed for biogas plants of 2.6 meter steel capacity gas production per day have also been developed in the country. The holders are 40 to 50 per cent cheaper than steel gas holder.

The National Environmental Engineering Research Institute (NEERI), Nagpur, has designed a night soil digester to prevent indiscriminate dumping of night soil and its unhygienic handling on farms in raw condition. The digester oxidizes organic matter rids the material of obnoxious odour, eliminates pathogenic organisms, provides sluge as manure, and yields methane gas for domestic use. The technology has been adopted at six places: Ramakrishna Mission, Coimbatore; Agriculture College, Rahuri, Maharashtra; Sulabh International, Patna; Burujwada village, near Nagpur; Garden Reach Municipality, Calcutta; and Delhi Contonment Board, Delhi. While in the Patna plant only night soil is used in others, mixtures of night soil and cattle dung are used.

An electrochemical method of preventing corrosion has been developed by the Central Salt & Marine Chemicals Research Institute, Bhavnagar, to reverse the corrosion process. The method is cheap and can be easily adopted by farmers in villages. It requires no supervision or maintenance.

The technology for production of biogas from cowdung and other animal wastes has been known in India for several decades now. The advantages of biogas as a fuel in the kitchen include elimination of smoke, improved in the sanitary and environmental conditions of homes and villages production of manure after digestion of wastes. Under a national project for biogas development implemented by DNES over 0.65 million plants were set up till December 1986. This would save over 2.5 million tonnes of wood equivalent Rs. 1,000 million a year. This will also produce as residue, excellent fertiliser valued at another Rs. 1,000 million a year.

Woodstoves

Chulhas (woodstoves) that do not emit smoke and use less wood are fast replacing traditional cookstoves in rural households ushering what is described as 'smokeless revolution' in India's country-side. About one million smokeless chulhas have so far been installed and 6,000 villages have become smokeless.

About 40 per cent of all the energy consumed in India goes for cooking food. The traditional woodstoves, made of mud and brick, in India's 112 million homes annually burn 133 millions tonnes of firewood and over 200 million tonnes of cowdung cake. But the stoves are so inefficient that rural women spend long hours in collecting firewood and working in kitchen filled with smoke due to unburned particles that Indian scientists say are carcinogenic. The improved cookstoves, having a combustion efficiency of more than 15 per cent have drastically cut down consumption of firewood. And because these stoves are designed to burn the fuel completely the kitchens are smoke free.

Some 51 models of improved cookstoves have been developed and introduced by various social organisations and research institutions like the Indian Institute of Technology (IIT) in Delhi, the Central Power Research Institute and the Indian Institute of Science (IIS) in Bangalore. The cookstoves vary according to the regions, type of food cooked, the fuel used. But the designs incorporate optimum size for combustion chambers, air inlets, grates for improving air circulation on fuel bed, dampers for draft control and baffles to improve heat transfer. Some models for permanent fixing in kitchens with or without chimneys. Others are portable type and are made of metal sheets or cast iron or a combination of the two. Apart from fuelwood most of the models can use cowdung, coal or pelletised agro-waste. The three-pan 'Astra Ole' stove designed by IIS requires only 60 grams of fuelwood for cooking one kilogram of rice in contrast to 400 grams consumed by traditional stoves. All new designs are tested and certified by the testing and training centres specially set up at IIT, CPRI and the Punjab University of Agriculture in Chandigarh.

This revolution has caught up in all of India's 25 states and union territories. The desert state of Rajasthan boasts of 135,000 improved stoves and 565 smokeless villages followed by the northern state of Haryana where 84,000 of these cookstoves installed in just one year have vastly changed the lifestyle of women in 200 villages. Funded and subsidised by DNES, the project is implemented by voluntary organisations, state nodal agencies and women's organisations such as the All India Women's Conference. DNES has so far conducted 1,547 training programmes to train people in the construction of the stoves. The master trainers in turn train men and women in their villages in 1986 alone some 81,000 persons had received training and DNES expects to have a workforce of 100,000 workers by the end of 1987. Each worker turns out five chulhas a day and earns Rs. 25 in wages.

While the fixed type chulhas are installed by government agencies and voluntary organisations, portable models are marketed at prices ranging from Rs. 38 to Rs. 63 by 12 private companies that have sprung up to cash in on the smokeless revolution. As an incentive to buyers, the government has abolished excise duty on fuel efficient wood burning stoves.

DNES has also developed community chulhas capable of cooking for up to 200 persons with fuel efficiency as high as 35 per cent. These have been recommended for hostels, hotels and canteens. The Tamil Nadu Government which has a mid-day meal programme for schoolchildren is planning to instal the improved community chulhas in the 33,000 schools whose mid-day meal project is being threatened by fuelwood shortage.

It is hoped that cookstoves, like bullock carts, will dominate the Indian rural scene for many more years. The new stoves are one important means of stretching the fuelwood resources and removing a major drudgery of rural women.

Biomass Programme

Biomass, in its variety of forms, is a potential source of renewable energy for use as solid liquid and gaseous fuel. It offers an important alternative to provide substitute to petroleum products. A number of activities relating to assessment, production, improvement, conversion, and utilisation of biomass were undertaken during the last four decades.

Production and Availability of Biomass

Increasing productivity of fuelwood trees and shrub species grown on problem soils—saline, alkali soils, degraded hill slopes, coastal alluvium, sand-dunes, laterite and lateritic soils, black soils, ravine lands—is an important national problem. For this purpose, it has been planned to set up a chain of Biomass Research Centres under different agro-climatic conditions of the country. In addition to the three centres already sponsored at Garhwal University, Srinagar, NBRI, Lucknow, and MIKID, Madurai. Two more such units at M.L. Sukhadia University, Udaipur, for Western Region and Purulia, West Bengal for eastern region have been approved.

The Biomass Research Centre at Garhwal University, Srinagar, is engaged in screening the mountainous tree species for the biomass potential. The studies include germinability of seeds, growth behaviour, light harvesting potential, photosynthesis and wood characteristics. Nearly 70 species have been collected and investigated for optimum temperature requirement under tropical and temperature conditions.

In most of the leguminous species, a high percentage of germination is recorded. However, *Albizzia lebbeck*, a promising fuel and fodder species, exhibits dormancy in fresh seeds and requires hot water treatment for a early and uniform germination. The seeds of *Toona ciliata, Cedrela, Alnus indica, Holoptelea integrifolia, Alnus nepalensis* and *Morning oteifera* gradually lost their viability. Observations on growth behaviour indicate that *Prunus cerasoides, A. Lebbek, Terminalia bellerica Dalbergia sissoo, Sapindus muscorosi, Olea glandulifera* and *Toona ciliata,* are promising fuel and fodder species for high biomass production in hilly areas. A mathematical equation based on the optical properties of leaves, by which the biomass production potential of a species under a particular climate can be predicted has been derived. The centre has designed styrofoam seedling tray measuring 30 cm in length and width and 10 cm in height. It accommodates sixteen seedlings and weighs only 5 kg with fully grown 6 months old seedlings. The tray can be used for raising as well as transportation of the seedlings. Its use minimises the overall investment per seedling and increase the chances of survival of the plants due to undisturbed root system before planting.

The Biomass Research Centre at NBRI, Lucknow, was set up to carry out studies on comparative evaluation of fast growing tree species suitable for saline-alkaline soils. In a high density trial *Terminalia arjuna* seedlings planted at 0.500.66, (corresponding to a density of 30,000 plants/ha) were significantly taller at an age of 3 years in comparison to widely spaced plants (10,000 plants/ha). The stem diameter increased with increasing density but differences between treatments were not significant. Soil up to 30 cm depth in the rooting zone, irrespective of density of planting showed a decrease in pH and exchangeable magnesium, an increase in organic carbon, exchangeable sodium, potassium and calcium content. Electrical conductivity did not indicate any significant variations.

In another experiment with firewood shrub species, *Sesbania aegyptiaca* proved significantly superior in terms of total biomass. Biomass yield tended to increase with an increase in plant population. Soil pH decreased and organic carbon content increased irrespective of the species. A pronounced increase in Ca/Na ratio was recorded under *Sesbania aegyptiaca* with highest value at a density of 75,000 plants/ha. Biomass production per unit area was highest in *Prosopis juliflora.* Amongst the five successful species with survival above 86 per cent, the most uniform average heights were achieved in *Acacia nilotica.*

The Biomass Research Centre at Madurai Kamaraj University, Madurai, is designed to carry out investigations in three major area of research selection of suitable fuelwood species for the semi-arid region; development of nursery technology and mass production of seedling; and selection of suitable rhizobial strains. Out of nine species selected, *Leucaena* was found to be more aptly suited for plantation under semi-arid condition on degraded land in Madurai district. It was observed to be significantly drought resistant. Photosynthesis and a number of related physiological parameters were correlated with the growth and bioproductivity of the selected woody biomass species. The species with high chlorophyll content showed a high degree of correlation in their photosynthetic rate. The use of the stem circumference measurements enabled to follow accurately the annual rhythm of the trees and investigate their wood productivity. A new phenotype of *Leucaena* was selected detailed investigations which is four times more productive than the normal one. As a part of the demonstration activitites of the Centre, seeds and seedlings of selected fuelwood species were supplied to four taluks of Madurai district for Rural Energy Plantation Programme for power generation.

A Biomass Research Project for Coromandal Coast was sponsored at the Institute for Offshore and Coastal Research of Visakhapatnam, Andhra Pradesh. The farmland at Lankelapalem with an area of 45 ha possesses four types of soils, viz., sandy loam, loam, clay and grvel. Seven species of legumes viz., *Albizzia lebbek, Cassia siamea, Leucaena leucocephala, Pithecellobium dulce, Prosopis juliflora, Sesbania grandiflora* and *Acacia and three non-legume (Ceiba pentandra, Casuarina equisetifolia* and *Eucalyptus hybrid*) were planted at the farm. In studies on comparative evaluation of 9 species *Sesbania grandiflora* appeared to be the most promising reaching a height of 8 meters within a period of 16 months only. All the transplants were found to be performing better in the loamy soil. The survival rate was observable around 85% at all the levels.

In order to correlate vield and development of plants with environmental changes, a Data Collection Platform (DCP) has been established with the support of the Indian Meteorological Department at the Research Farm. This platform is equipped with instruments for measuring various climatic parameters on a regular basis. The data collection and retrieval are monitored by geosynchronous satellite INSAT-1B randomly in a nurst mode every hour.

Under the project, "An Investigation on the Fuelwood Yielding Plants with Special Reference to Their Improvement Through *Cytogenetical* and *Culturing Techniques*", studies were carried out on the following aspects: assessment of chromosome status of the selected fast-growing fuelwood plants; genetic improvement of the desirable plants through polyploidization and induction of mutation by application of different physical and chemical mutagens; rapid clonal propagation of the selected plants through *in vitro* culture technique; exploration of the possibility of improved seed germination technique for faster multiplication; and the study of the growth rate and biomass yield potential of the selected fuelwood plants in different agroclimatic zones.

Detailed cytological analysis of the four species has revealed that *Leucaena leucocephala* is a polyploid species having a very high chromosome number (2n = 104). *Sesbania gradiflora* has the lowest number of chromosomes (2n = 24) whereas *Acacia auriculiformis* and *Prosopis juliflora* have 2n = 26 and 52 respectively. In the species chromosomes are minute in size. Difficulty in seed germination as well as profuse cytoplasmic inclusions poses serious limitations in working out of karyotypes in other species. Complete regeneration in *in vitro* condition has been successfully done in case of *Sesbania grandiflora.* Profuse shoot multiplication in *Leucaena leucocephala* should be utilised for rapid propagation after successful rooting becomes possible. A large number of plants with vigorous growth have been recorded after gamma-irradiation in *Leucaena leucocephala, Acacia nilotica* and *Prosopis juliflora.* This opens up the possiblity of higher biomass yield and faster growth after irradiation in other materials also. Similar phenomenon has also been noted after treatment with certain chemical mutagens. Final screening of the mutants may yield some useful variants with increased biomass yield. Induction of polyploidy has been successfully done in case of *Sesbania grandiflora.* Assesment of biomass yield and growth behaviour revealed that *Acacia auriculiformis, Sesbania grandiflora, Leucaena leucocephala* and *Dalbergia sissoo* have maximum potentiality in all the regions. Rapid seed germination technique has been standardized in some of the materials.

A number of energy-rich leguminous trees and latex producing plants are under investigation at the Applied Botany Section, Kharagpur. *Calotropis gigantea* (Akanda), a hardy weed of arid and semi-arid regions, produces latex (M.W. 10,000) which is a potential source for hydrocarbons. Methods have been developed for micropropagation and regeneration of plantlets from *in vitro* callus cultures of *Albizia* (Siris), *Samanea* (Rain tree) and *Peltophorus* (Copper pod). Experimentally it has been shown that for large scale micropropagation, as many as 30 to 40 plantlets can be regenerated from a stem segment of 0.5-1.0 cm. during a period of six weeks only. The usual high mortality of the plantless on transfer to soil can be overcome by induction of extensive rooting and hardening under shade. It has been established that non-comittant caulogeny and rhyzogeny is the chief reason for high mortality of potted plants.

Jojoba (*Simmondsia chinensia* Link; Schnd), a supplementary source of lubricating oil, has been tried in the semi-arid and sub-humid climates in the western and eastern regions of the country, respectively. The performance of the species is significant with two fruiting cycles and oil contents maintained at about 50%. Thirty-six selections in the west coast and 10 selections in the east coast have been made with clear distinct plant types. Multi-locational trials have been initiated with the help of government departments, universities, research institutes and private entrepreneurs. In one of the plantations in Gujarat, flowering and fruiting has commenced in two-year-old plants on a private farm.

Morphological and biochemical work has been initiated to identify the sex at an early stage so that sex differentiation should not be constraint in making large-scale plantations. Vegetative propagation by air-layering, stem cutting and tissue culture have been undertaken. The progeny P, P, and P have been planted and the observations of mother plant of the 36 selections made in the semi-arid climate.

Indian coastline stretches about 6,000 kms and sea-weeds are utilized for agar and alginate extraction. The utilization of the seaweed biomass as a substrate for biogas has been sponsored at Marine Alga Discipline, Central Salt & Marine Chemicals Research Institute (CS&MCRI), Bhavnagar. Experiments carried out on the biogas from seaweeds indicated that *Sargassum tenerrimum*, a species of brown seaweed, along with 10 to 25% cowdung and marine microbial culture can yield 90-100 litres of biogas per kg. (dry seaweed) over a period of 90 days only.

Conversion and Utilization of Biomass

Studies were carried out on hydro energy of biocrude samples obtained from *Euphorbia nerifolia* and *E. ryleana* and *Cryptostegia grandiflora* and *Calotropis gigantea* using *Silica alumina* based catalyst ratio of 10:1 at IIP, Dehradun. The operating temperatures and pressure were 380-450° C and 80-150 cm, respectively. In a typical run, products obtained from the latex processed biocrude were: gases (6.61) naphtha (23.85) kerosene (21.97) gas oil (18.22) heavies (26.47) water (0.95) coke and losses (1.93%). In the case of biomass processed biocrude the products were gases (6.46) naphtha (16.17) kerosene (28.26) gas oil (16.17) heavier (12.93) water (90.97) and coke and losses (19.04%). Over 90% of the hydrocarbons in the lower boiling products have been identified. These studies clearly demonstrated the feasibility of obtaining petroleum hydrocarbons from renewable sources.

Development of products using jojoba oil or its derivatives was continued at IIP, Dehradun. Using neat jojoba oil as a base stock for two stroke engine oil formulation was developed. The properties and screening test of this formulation were found to be comparable to those of commercial two stroke engine oil with respect to wear, scuffing and deposits. Conditions for the preparation of sulphurised jojoba oil were standardised and the product was evaluated for wear and load carrying capacity. Comparative study with commercial additives was also carried out. The sulphurised jojoba oil so developed was found to have promising application as an extreme pressure (EP) additive; a formulation of industrial gear oil developed and the properties of this oil were evaluated. The formulation meets all the requirements of IS-8406 and it has been found to be comparable to commercial oil. Jojoba oil derivatives with higher sulphur content for use as EP additives are under evaluation.

Vegetable oils can serve as possible substitute or supplement to diesel oil. Vegetable oils have calorific value and ignition quality approximating to those of diesel oil; however, their viscosity and carbon residue is very high. This leads to pumping and vaporisation difficulties in engines and also heavy smoke emission in the exhaust. In order to overcome these problems, two different approaches, namely making the diesel engine more adiabatic and esterification of the vegetable oil with methyl or ethyl alcohol have been tried at IIT, Madras. In the first case, namely making the engine like piston, cylinder liner and cylinder head are thermally insulated either by ceramic coating or by air gap. With the heat losses in engine drastically reduced, the air temperature after compression increase substantially over that of the normal engine. Hence, the evaporation and ignition of vegetable oils is made easier. In the second approach, vegetable oil is reacted with ethyl or methyl alcohol in the presence of catalysts to form the eather of that oil and glycerine. By this process, the viscosity is brought down to the level of diesel oil and also the carbon residue is reduced. The use of karanji oil, salseed oil and rice bran oil is under investigation at IIT, Madras. An engine has been converted to be adiabatic and karanji oil has been tried on this engine. The ignition delays the rate of pressure rise and the peak pressure are higher than for the normal engine, indicating the benefits of preventing heat losses.

Gasification of Biomass

Three projects on the development of a village level gasifier based on wood and agricultural residues for irrigation purposes have been undertaken at IIT, Delhi, and Jyoti Solar Energy Institute, Gujarat. A gasifier-cum-clean-up system has been developed at the Chemical Engineering Department, IIT, Delhi. The gasifier unit is very simple in construction which will enable even an unskilled farm labourer to operate and maintain it easily. A wetted wall cyclone has been designed for effectively cooling and cleaning the producer gas from the gasifier. A simple batch drum charring unit and also a semi batch charring kiln have been designed and developed for charring biomass of various types. These units are under successful operation. The gasifier system has loged more than 200 hours of trouble fee operation, producing a gas of 820 KCal/m3. A 5 HP C.I. engine pump system supplied by Project B team from Mechanical Engineering Department, IIT, Delhi, has been successfully operated at about 70% diesel replacement.

Research and development work on efficient utilisation of producer gas in combustion engines has been in progress at the Mechanical Engineering Department of the Indian Institute of Technology, Delhi. Existing 3-5 HP petrol engines and diesel engines have been modified to operate on producer gas fuel. Extensive performance and emission tests have been carried out on 5-20 HP stationary and automotive type of petrol engines duly modified for 100 per cent producer gas substitution. The 5 horse power diesel engines of the type widely used for irrigation purposes have been modified to operate with up to 80 per cent full load energy substitution by producer gas. Engine design and operating parameters such as injection timing compression ratio, intake system, etc., have been experimentally optimized to achieve efficient combustion of producer gas with an annual saving of more than Rs. 5,000 in diesel cost per engine pumpset/gen set of 5-6 KW rating on a 10 hour per day operating basis.

Under the gasifier programme, Jyoti Solar Energy Institute, Vallabh Vidyanagar, has developed a gasifier system capable of running 3.7 KW engine-pumpset for irrigation and installed a demonstration unit in a farmer's field at village Johr, 7 km from the Institute. It is a down draft gasifier with facility for air pre-heating. The system has run for about 500 hours without any technical problem. It consumes wood at the rate of 3.4 kg/h and gives an average diesel replacement of 60 per cent. The operating cost of the unit is 70 P per KWh of shaft power whereas with electricity and diesel, the corresponding values are Re. 0.87 and Rs. 1.07.

Magneto Hydro Dynamics (MHD) Technology

A small scale magneto hydrodynamics power generator set up at Tiruchirapalli in Tamil Nadu is providing data for design of bigger MHD plants that will produce power cheaply and operate of a greater efficiency than existing coal or nuclear plants.

The experimental run for power generation was carried out by the Bharat Heavy Electricals Ltd. in collaboration with the Bhabha Atomic Research Centre, Bombay.

The principal of MHD power generation involves direct conversion of thermal energy into electrical energy and the process is being experimented upon several countries like USSR, USA, Japan, China, the Netherlands, Australia, Poland and Finland.

According to a senior BHEL scientist the science of converting thermal energy to electricity through MHD involves the expansion of superhot (2,800 K), electrically conducting gas against the retarding force of a strong magnetic field to produce electric power directly. In effect, the turbine and generator are combined in MHD into a single unit but without any moving parts.

It is well established that flame temperature of fuel oil, coal, natural gas or power gas in reaction with preheated air at 1,200°C, and 5 atm. is about 2,500°C. Thermal ionization occurs at this temperature, but the level of electron density is insufficient to induce economically viable electric conductivities in the combustion products. However, the addition of an easily ionized metal seed, such as cesium or potassium, in a concentration of about 1% during the combustion process provides the required conductivity in the range of 10-100 mho/m3. The apparatus which accomplishes these arduous tasks is the MHD combustor.

The combustor is followed by a nozzle which accelerates the plasma to subsonic or supersonic velocities. Deceleration and electrical energy extraction occurs in the MHD generator, which is positioned in a high magnetic field of 4-5 tesla. The cooled exhaust-still at high temperature (2,200K) carries the remaining (a large) portion of the input energy and this is used for further power generation in a rankine plant downstream. After passing through the steam generator, the exhaust is scrubbed to separate the expensive seed and is then ejected via the stack. The seed is collected and processed to remove impurities and then recycled. Later DC electrical output is inverted to AC and heat losses through the combustor and MHD generator are recovered in separate loops.

The coal based MHD research project in India, sponsored by the Department of Non-Conventional Energy Sources, aims at the creation of a suitable base for research and development work in the field of MHD power generation by setting up a thermal power level of 5 MW.

BARC has developed most of the key components of the facility including the MHD generator, a 300 tonne of electromagnet, special plasma diagnostic equipment, high-temperatue ceramic materials and as control and instrumentation system for the experimental plant.

The plasma generation experiments, carried out during March 1985, yielded MHD-grade plasmas at 2,700K and very high electrical conductivity. Following the plasma generation run, the first successful power run of the project was accomplished in August 1986. A cold oxidiser with 60% oxygen enrichment was used during the power run.

The experiments conducted so far have shown that the new technology could increase the energy conversion efficiency from the currently obtained

29-30% in India to 46%. Further technological advances may lead to more attractive efficiency. Besides, an annual saving of 8,00,000 tonnes of coal per 100 MW of installed capacity can be achieved at a capacity utilisation of 70%.

Studies further found that the quantity of heat discharged from an MHD-steam plant is less than 50% of that from the best conventional plant and less than 25% of that from a nuclear power plant. Hence, MHD-steam plant could be located where fuel is available in plenty but cooling water is limited.

The MHD-project initiates a two-year experimental programme. These experiments are expected to generate technical operational and economic parameters in the field of MHD power generation which will be useful in further upscaling and eventual commercialisation of this technology.

The experts believe that MHD could become a major electric power generation technology; in fact, the commercialisation of this process is anticipated as early as middle of 1990s. The aim and effort in MHD development that has so far received world-wide attention, and has the most immediate large-scale application, is focused on the prospect on improved energy conversion in fossil fuel based systems to produce power for a utility grid.

Moreover, the costs of conventional fossil fuel fired plant has been rising steadily since the early 1970s because of increased regulatory restrictions on releasing pollutants to the atmosphere. MHD, the experts say, is an environmentally clean system. Besides, it is more efficient and less polluting energy alternative holding promise of generating electricity at a reduced cost.

Wind Energy

In the field Wind Energy Research & Development efforts were oriented towards improvement of existing designs of wind pump system, development of new windmill design and on the development of small battery chargers and wind electric generators.

A design review of the 12-PU-500 windmill was carried out in order to assess the adequacy of the present design for the intended duty. This has led to the identification of design weaknesses and the improvements needed in various sub-systems such as pump, transmission and furling mechanism for better and more reliable performance. A new design of 12-PU-500 windmill has been developed in Gujarat Extensive field trial of the new design is proposed to be taken up.

Under a project sponsored at National Aeronautical Laboratory (NAL) for development and field testing of sail type windmills, different configurations were tried successively for a "trapezoidal" sail type rotor having "self activated twin spoiler" regulation device which had earlier shown significant promise in wind tunnel tests. From the experience gained with the sail type prototypes, the sails were replaced by a 3 bladed metal rotor of 7.5 m diameter, designed for tip-speed ratio of 4 : 0. The rotor is coupled with 2 HP centrifugal pump. The starting speed is 12-13 kmph and rated speed is reached in 21-22 kmph, when the pump delivers 21,000 lph. The output is particularly high in wind speeds upwards of 16 kmph, indicating that the windmill is more suitable in windy areas. The windmill has been in operation since end of August 1985; initial tests have shown significant regulation capability. Four prototypes of the windmill with minor modifications in the rotor and gear boxes will shortly be installed for field testing.

Information and Communications

INDIA IS undergoing a major social and economic revolution through new information processing technology of communications and computers. This revolution is not confined to the area of science and technology: It is bringing about dramatic changes in the way Indian people live and work—and may be even think.

In the home, microchips are entering through VCRs, food processors and personal computers which are no longer just being used for playing games: more and more people are using them to actually work at home, sometimes on a permanent basis. At school, computers have been welcomed into the classroom and a new generation of "microkids" are growing up who know more about computers than their parents and even some of their teachers.

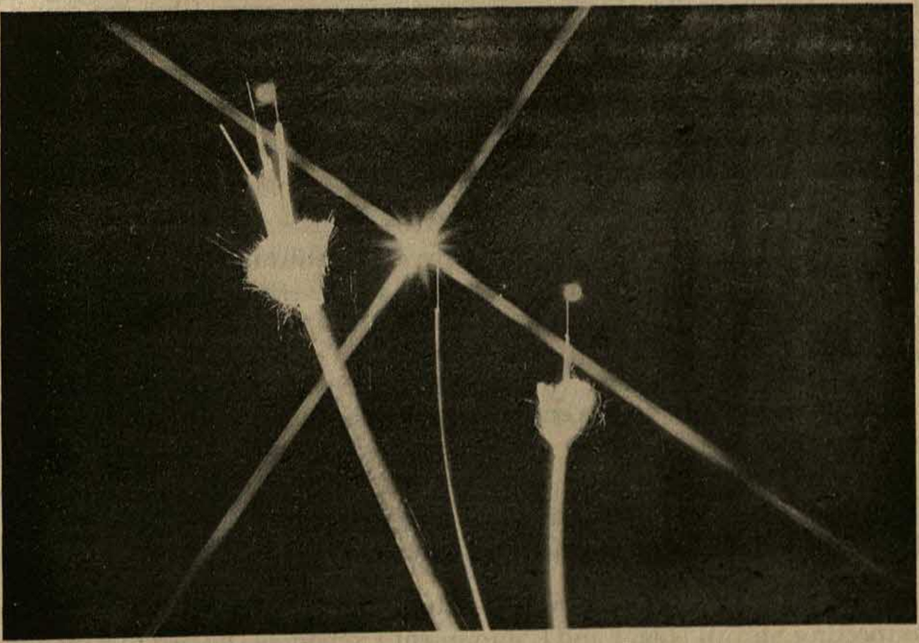
The information technology, based on electromagnetics, in many interconnected forms, is transforming news-gathering and transmission in the premier news agency of the country, the Press Trust of India. Besides, it is transforming the system of hotel, railway, airway and theatre bookings, meter-reading and weather forecasting. The personal computer is marching into the offices where it is replacing paperwork and improving productivity, customer service and job satisfaction for some.

Fibre Optics

In the field of fibre optics, India is now poised to become the first developing country in this part of the world to make use of fibre optics, the new technology of transmitting information with beams of light, to solve many problems being faced in telecommunications, industry and medicine.

It is a new technology that has enormously increased man's capacity to move words, pictures and data from place to place. Quite simply, telephone conversations. television broadcasts, computer data, or any other message can be translated into light wave and sent through glass wires instead of the conventional technique of translating them into electrical impulses and sending them through copper wires. The information transmitted through optical fibre is in digital form, as pulses of light, much like those that might be used transmit Morse Code. Theoritically fibre optics can seem as miraculous as the microchip in whose wake they follow. Tiny strands of very pure glass as thin as a human hair can carry up to 8,000 simultaneous telephone calls in a core just 1/200ths millimetre across.

In India, over 22 research institutions are engaged in systems various aspects of optical-fibre, communication fibres, components and associated material technology. The work is going on relating to various aspects of materials and systems for optical communication such as drawing of low-loss optical fibres, splicing and connecting techniques, modulation and demodulation techniques, multiplexing and demultiplexing techniques and system studies. The Telecommunication Research Centre in Delhi has developed a terminal equipment for a 120-telephone channel system.



Indigenous optical fibres

The Indian Institute of Technology in New Delhi has a facility for testing fibres and engaged in perfecting already existing measurement techniques and trying to develop new methods to characterise fibres (pulse dispersion, attentuation, refractive index profile measurement).

The Central Electronics Engineering Research Institute in Pilani has developed silicon avalanche diodes for detecting and decoding laser pulse at the receiving end, and the Instruments Research and Development Establishment in Dehra Dun and the Central Scientific Instruments Organisation in Chandigarh have developed a variety of fibre optics components for defence. Besides, a variety of fibre-optic components developed for various applications are: light-guides of different lengths and aperture, aligned flexible fibre bundles used in sigmoidoscope, fibre-scope and traffic signs; solid fused bundles or face plate.

The Defence Solid State Physics Laboratory in Delhi has succeeded in fabricating the gallium-arsenide lasers, while CSIO is developing a machine for drawing plastic coated silica fibres. A more sophisticated facility at the Central Glass and Ceramic Research Institute in Calcutta has already produced experimental quantities of 'graded-index' multimode fibres.

Research and development and measurement technique related to characterisation and evaluation of communication grade fibre are being done at Indian Institute of Technology (IIT), Delhi, and Central Scientific Instruments Organisation (CSIO), Chandigarh. These institutes are capable of performing well-identified and complementary tasks if they are assigned to them in a coordinated manner. Other IITs are also in the process of setting up similar facilities.

Research in the field of launching optical signals and detection of signals with imported sources is going on in several institutions of the country. Work is also going on terminals circuitries for coverting sources detectors into different systems required transmitters receivers and also repeated stations.

IIT, Kharagpur, has recently started an M.Tech. course covering technology of optical fibre communication systems with its associated devices, materials and components to meet the manpower requirement. Courses on optical communication are also being given at some of the other IITs, Indian Institute of Science and some universities.

In India, the first optical fibre communication system was set up in Pune connecting Shivaji Nagar and Cantonment Exchanges. Buried two metres underground, the glass fibre imported from Japan provides 120 telephone channels and has been functioning without any fault since 1979. A prototype of 40 Mb/s per capacity has been developed by the Telecommunication Research Centre and Indian Telephone Industries will commence production of this item by end of this year. The Hindustan Cables Ltd. will soon start manufacturing of optic fibre cables at its factory in Naini near Allahabad.

Fibre communication systems in the country have successfully passed through the demonstration stage and are now poised for large scale commercial exploitation. In order to have coördinated efforts and avoid duplication in this area, it may be necessary to initiate an integrated technology development programme in the country bringing together a number of institutions working on various aspects of materials and systems for optical communication.

Experts of Central Scientific and Industrial Research say the enoromous information carrying capacity of glass fibre is due to the fact that light wave have a high 'bandwidth' or, in other words, greater 'room' to accommodate messages than electrical waves sent through copper wires. In fact, a single fibre can carry 30,000 telephone calls or 20 television programmes simultaneously. Optical fibre has other advantages too. While the world's supply of copper is running out, sand—the principal ingredient in glass—is just about endless. Being thin, more glass fibres can be fitted in crowded ducts under streets of cities. While a typical copper telephone cable is eight centimetres thick and weighs four to twelve kg per meter, a glass cable a centimetre thick weighs about 135 gm. Glass fibre is also easier and cheapter to maintain.

The National Information Centre is establishing a network with regional centres and with large data processing systems at Delhi which in turn are connected to government departments and agencies. The primary objective of NIC is to provide computer based management information system service and related support facilities to the various ministries and other offices of the Union Government. Towards this goal, a star type computer network (NICNET) has been developed by NIC, linking up 20 mini-computers and 60 interactive terminals located in the various Government offices in Delhi to the host computer CYBER CDC170/730 at NIC serving some 40 ministries. It will soon enter the second phase of its operation in which the NICNET will be extended to the various state capitals to enable centre-state exchange of information. To begin with, the areas to be covered will be agriculture, health and education.

INDONET is an integrated information management and distributed data processing facility spanning the entire country. It is aimed towards revolutionising data processing within the country. Under this project, a computer network is being set up in Bombay, Delhi, Calcutta, Madras and Hyderabad. It will provide local computing facilities to small and medium scale sectors to develop highly specialised software in areas like engineering design; structural analysis and management sciences. The project is being implemented by the Computer Maintenance Corporation (CMC) Ltd.

Communications

In the field of communications, from essentially a telegraph network in the late forties, the Indian telecommunication network facility has grown significantly over the years with the acquisition, adaptation and indigenous development of newer technologies.

The country has now developed the necessary capability to manufacture her own sophisticated materials and equipment. In this respect, mention may be made of switching and transmission systems and creation of support facilities, e.g., telephone instruments, digital telephones, key telephone and microwave and line systems. The major areas in the plan of Indian Telephone Industries relate to digital telephone subscriber apparatus and instrumentation, telemetres, RTs and powerline carrier communication systems and integrated communication systems.

Today the network provides for nation-wide dialling, enabling speech transmission, long distance links through satellites and fairly efficient switching systems like the electronic stored programme controlled (SPC) switching systems. The network comprises more than 3.1 million telephone connections with about 10,000 telephone exchange supported by microwave systems, coaxial cable systems and ultra high frequency (UHF) systems of different capacities. Assimilation, incorporation and integration of newer technologies like SPC electronic TAXs and local exchanges, digital trunk exchanges, SPC telex exchanges, integrated SPC local/trunk exchanges and digital microwave systems are beginning to give a valuable boost to the efficiency to the Indian telecommunication network facilities.

The scenario for new services is now set with demands for data and facsimile transmission facilities. Plans are afoot to set up a commercial services, network with satellite communication terminals installed atop business premises and using the satellite channels. Among the institutions gearing up to meet the growing demands and technological challenges are the Telecommunication Research Centre (TRC), New Delhi, Indian Telephone Industries (ITI), Bangalore, Hindustan Teleprinters Limited, Electronics Corporation of India Ltd. (ECIL), the Computer Maintenance Corporation (CMC) and Bharat Electronics Limited (BEL).

The ITI is the main national organisation providing hardware for the network. Specialised communication equipment needed by defence, power, administration, railways, Oil and Natural Gas Commission and other organisations are met by ITI. The BEL and the ECIL are also producing relevant equipment needed for these services.

A beginning has been made to introduce digital switching system technology in the country. By the end of this decade, 54 per cent of the local exchange lines will be of electronic type, 26 per cent of crossbar type, the rest of strowger and manual types. Also 44 per cent of the transmission medium will be of digital type. The ITI is engaged in a project for manufacturing digital electronic switching systems (ESS) at Gonda, with an annual capacity of 0.5 million lines based on technology transfer room CIT-Alcatel of France. The second ESS factory to be set up in Bangalore and another to produce digital TAX equipment meant for augmenting the national subscriber trunk dialling network at Palghat will also be based on indigenous technology.

The TRC is a premier institution engaged in the development of various facilities for telecom systems. It has established an extensive network of earth stations for satellite communication, and introduced digital transmission network through radio links and modern means of transmission media like optical fibre communication links. Using the public switched telephone network (PSTN), subscribers' terminal equipment and computer ports are now permitted to be connected as attachment to telephone in the public telephone system, enabling them to dial a computer port and communicate through the subscriber terminal equipment.

With a view to introducing digital transmission the TRC is conducting trials on 140 Mb/s system on coaxial cables route. A long distance trunk route of 140 Mb/s optical fibre system is also being set up for trials. To meet the estimated needs of a changeover from analog to digitally-based systems, it is fabricating equipment adapted to digital technology. An equipment incorporating latest techniques in pulse code modulation (PCM) has also been evolved.

In addition to large capacity main telephone exchanges using digital technology, the institute is developing small capacity electronic exchanges for rural communication facilities. It would further be augmented with the implementation of a 4,000 route km fibre optic cable system of graded index type, to be manufactured by the Hindustan Cables Limited.

The TRC has developed an exchange with the facility for direct dialling by subscribers into the national network. Based on a microprocessor system, it is powered by AC main supply or solar panels. Further the institute has fabricated small capacity electronic PABXs, compatible with ordinary telephone instruments as operator console for use in small offices.

In the data communication field, TRC is working on projects for introducing modern non-voice services popularly known as video-tax, telfax and teletext for transmitting services in different forms at fast speeds over the public telecom network.

The state-of-art message switching systems is also progressing in civil aviation, meteorology and defence. For establishing data communication network steps are under way to generate the necessary software, as also production of equipment such as terminals, multiplexers and connectors.

Even remote towns can be connected to the national telephone network, with the help of the most advanced digital integrated local-cum-trunk exchange developed by the ITI, Bangalore, in collaboration with the TRC. This exchange can work as a local tandem or trunk exchange or in any combination. It uses the digital form in the line circuit, and handled in the line circuit in the digital form only. Further developments on this exchange will enable easy expansion from 64 to 2,048 lines without causing any interruption to subscribers.

Computers have been introduced to modernise telecom business and consumer services in the large telephone system. The first phase of the project in operation involved directory enquiry service. The facility is being extended to cover commercial billing fault analysis and fault control, traffic accounts. The Institute has effectively used thin-film technology for producing MIC modules for 2GHz, 6GHz, and 7GHz equipment and ground communication equipment. The technology is also being adopted for realising IF pre-amplifiers and special ECL compatible termination network. Chip carrier technology is being developed for complementing miniature package leading surface mounted devices, technology in an assembly activity. It has also evolved a push button telephone with radial facility.

The National Centre for Software Development and Computing Techniques (NCSDCT), in Bombay, has provided the R&D and human resources base for Indian software development and exports. This is now being enlarged and upgraded into a National Centre for Software Technology (NCST) to be the focal point for all software activities. Besides providing a policy framework for software development, use, and exports, the new agency will also provide training, disseminate software information, and offer consultancy services in both software and systems development for specialized application. The NCST will also develop the expertise that NCSDCT has already built up in data base management computer-aided design, computer graphics, computer networks, digital-type design and text processing of Indian language scripts.

Of the many recent measures aimed at software development and exports, the concept of Software Export Technology Parks (SETPs) envisaged by the government is a significant one. These parks will be resource centres for software exporting groups.

The following examples give some idea of recent domestic applications of software developed by Indian companies:

- A package intended to help garment manufacturers was originally developed for the export market, but has been bought by leading manufacturers in Bombay & Delhi.
- A hotel management system for front office, back office, catering, house keeping, restaurant and other facilities is being used by leading hotels in the country.
- The domestic airline, Indian Airlines, recently introduced a software system to handle reservations, cargo information, crew scheduling and aircraft inventory.
- CMC has developed software for computerized news editing and switching of teleprinter transmission for the Press Trust of India. It has worked out a national rail reservation system for Indian Railways.

Among the system software achievements of Indian companies are : Productivity tools such as program and system generators and skeleton generators. Software for designing Indian-language type fonts is considered a major achievement. In addition, some of the companies deal in operating systems/cross compilers for BASIC, PASCAL, COBOL and FORTRAN.

The Indian software industry, however, is about to face the majo challenge of meeting domestic demand for computer aids in agriculture, poverty alleviation schemes and rural development. In sophisticate areas, such as country's space programme, nuclear energy development an oil exploration, the indigenous software industry has already made mark.

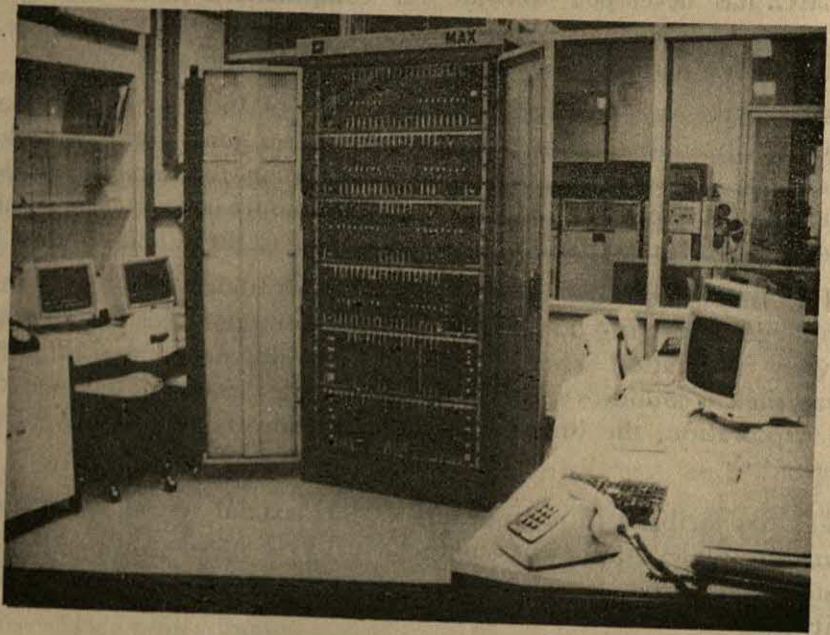
ITI has facilities to manufacture 4 MHz coaxial system, second orde digital multiplex equipment, single channel VHF system, 8 Mb/s fibre opti system, interstice system and centralised traffic control equipment for metr railways.

Besides an electronic store and forward gentex system, developed b ITI, has been introduced in Madras. Facilities for circuit switching fo teleprinter terminals located in telegraph offices have been provided t avoid manual retransmission of messages. Similarly store and forwar systems based on VLSI chips and microprocessors ensure efficien retransmission and speeding of telegrams.

The telecom factories at Bombay, Calcutta, Jabalpur and Bhil manufacture manual exchange, automanual equipment, coin bo telephones, testing devices, cable distribution and termination instruments and microwave towers.

Recognising the importance of telematics in information Technology, which provide means of communication, the Government has set up the Centre for Development of Telematics (C-DOT) which has developed India's first ever multipurpose 128-line electronic digital private automatic branch exchange (PABX) and other advanced electronic exchanges.

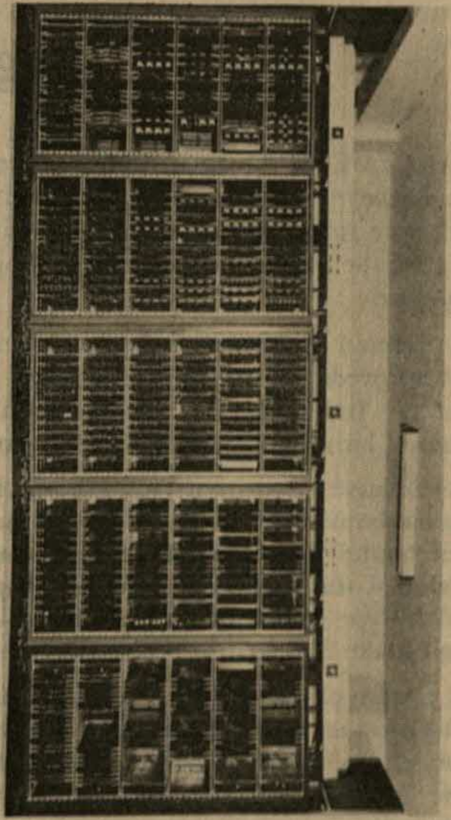
The salient features of the PABX are call, transfer call forwarding, and automatic call back required in hotels, hospitals and business houses. Another feature is that it provides simultaneous voice and data capability enabling interconnecting computers to exchange information. Apart from the extension to extension call, the system also provides the basic features required under the Indian environment. Additional sophisticated features can be provided with new software releases.



C-DOT 512-line telephone exchange.

C-DOT is designing a family of switching systems to meet not only the immediate but also the progressing needs like data, teletext, facsimile and videotext of developing countries. C-DOT 128p PBX is being manufactured by 36 manufacture by ITI along with 13 state electronics corporations with a total annual capacity of about 3.5 lakh lines. ITI is also setting up manufacturing facility of 1 lakh lines per annum of 512p C-DOT exchange. The large 16,000p exchange will soon be manufactured by ITI.

For defence applications in the area of communication systems, both line and transmission equipment in HF, UHF, VHF and microwave frequencies in narrow and with bandwidths are manufactured in different configurations. Such systems include line of sight as well as troposcatter satellite links. An integrated network of different communication systems employing both analog and digital mode of transmission is in advanced stage of development.



C-DOT 4,000-line telephone exchange.

Development plans include use of fibre optic links for integrating various subsystems to minimise electromagnetic interference in command and control systems. The production of defence grade ratio relay equipment has been enhanced with the participation of Hindustan Aeronautics Limited, by increasing the BEL's production capacity and speeding up the design and production of next generation equipment. Both these organisations have started production in 1987.

Agriculture

RECENT ADVANCEMENT in agriculture in the country has been phenomenal. At no time in history has any nation been able to feed so many millions and still store some for lean years. Producing over 150 million tonnes of foodgrains, the country now is able to supply its surplus foodgrains to other nations.

This has been rendered possible with the development of high-yielding crop varieties, improved production technology and the pragmatic innovativeness of the Indian farmer who has enthusiastically adopted modern techniques of farming developed in the country.

Introduction of relative insensitivity to photo-period and temperature through breeding has been responsible for the development of 'period fixed' rather than 'season bound' varieties. This resulted in mixed farming which involves crop/livestock integration and mixed cropping involving the simultaneous cultivation of two or more crops in a field and multiple cropping leading to take 2 to 4 crops per year in the same plot of land.

The change of pattern of the genetic architecture has been an important factor in increasing productivity of crops during this century. Hybrid maize, dwarf rice, hybrid sorghum, hybrid pearl millet, dwarf wheat, and hybrid cotton are some of the important milestones. Research efforts are concentrated on developing plant types to suit various agro-ecological conditions prevailing in the country.

The development of single and double dwarf in wheat, composite varieties of maize, varieties containing better nutritive quality, the long-staple cotton have further added to the total productivity of the crops in the country. Breakthrough in crop production was also possible owing to systematic efforts on plant protection research through multiple programmes, such as breeding resistant varieties, chemical control methods and cultural methods. Significant success has been achieved in combating the menace of diseases and pests through the development of resistant varieties in rice, wheat, gram, potato, maize, arhar and several other crops. Some of the pests like pyrilla pest of sugarcane, castor-semi-hopper have been shown to be successfully controlled through biological control methods.

Cereals form the most important food crop of the country. Rice is grown under varied conditions all over the country in an area of about 39 million hectares. Till recently tall native indica varieties were the only ones grown and the productivity was very low and the total production in 1965-66 was only 862 kg/ha with total production of 30.5 million tonnes. The discovery of the dwarfing gene in 'Dee-Geo-Woo-Gen' in Taiwan and the introduction of Taichung Native 1' and 'IR8' varieties from the International Rice Research Institute, Philippines, demonstrated for the first time the high production potential of dwarf fertilizer-responsive varieties of this crop. Variety 'IR8' and 'Jaya' soon occupied vast areas in the irrigated areas of the country. It was soon realised that no single plant type could suit the diverse rice conditions of India. In the last decade or so a large number varieties have been released by the Central Varieties Release Committee of the Ministry of Agriculture and as many as 70 varieties have been released by the State Departments of Agriculture suited to local conditions.

The coverage of area under high-yielding varieties and their impact has been quite variable in various parts of the country. The most spectacular impact has been in the non-traditional rice areas where good water management is possible and the comparatively drier climate is conducive to freedom from pests and diseases. The impact has been least in the traditional rice areas of north-eastern India where rice is grown under humid, monsoon medium deep water and disease-prone conditions. This is where bulk of the rice area of India lies.

The dwarf varieties are not only significantly superior to tall indicas in their response to fertiliser but they also give higher yields compared to the tall varieties even under low or medium doses of fertilizers.

In the national demonstrations at the farmers' fields, the new varieties have reached a productivity of 6 tonnes/ha and above as against the highest national average of 1.4 tonnes/ha. The new dwarf varieties have high harvest index (grain : straw ratio) and thus make more efficient use of applied fertilizer and photosynthetic energy. As indicated earlier, the impact of new technology on rice production has been quite variable in different parts of the country. Whereas in the northern and southern states with good water management, the yields have moved up fast, they have been almost static in the north-eastern areas of the country.

One of the reasons for non-adoption of improved rice technology in monsoon areas of the north-east region has been the susceptibility of the new varieties in humid areas to pests, lack of optimal use of fertilizer, poor water management and small and fragmented holdings. The important pests are stem borer, gull midge and green and brown leaf hoppers. The latter two are also vectors of 'Tungro' virus. Diseases like blast and blight take a heavy toll. In recent years, work has been intensified to impart multiple resistance to the future varieties as an important breeding objective.

Wheat is the second important crop of the country occupying about 24 million hectares. This crop is grown extensively in the northern parts of the country during the comparatively dry winter months and the crop presents fewer management and insect and pest problems. The production of this crop has also stagnated around 10-12 million tonnes up to the mid-sixties when new dwarf Mexican varieties were introduced. The bulk import of varieties like 'Sonora 64' and 'Lerma Roja' served to demonstrate the potential of the new plant type. Varieties like 'Kalyansona' and 'Sonilka' held the field for quite long but soon a number of varieties were evolved to suit the various agro-climatic regions.

The main emphasis in the breeding of wheat varieties in the country has been resistance for rusts. In the recent years, this has been a great factor in sustaining the wheat production in the country. The diversification of the varieties pattern and the saturation of the endemic areas of the disease in the Himalayan foothills and Nilgiri and Palni hills in the south with highly resistant varieties has paid rich dividends. Despite all this, it is apparent that with the change in the biotypes of rust organism the resistance of the varieties is short lived. To combat the disease on a long-term basis and to impart stability to production, the multiline approach of breeding was started in 1967-68 whereby lines of the currently popular varieties like 'Kalyansona' and 'Sonalika' with diverse genetic source but having the agronomic characteristic to these popular varieties have been evolved so that a mixture of 6-10 of these lines constitutes one multiline variety. Three such lines namely, 'KSML 3', 'MIKS 11' and 'KML 7406' have been released in India for the first time.

The Indian wheat breeders have developed a large number of varieties and given out to cultivation. These have high degree of resistance to rusts coupled with high yield, lodging resistance and acceptable grain quality. They have developed varieties both for irrigated timely sown, irrigated late sown and rainfed conditions. India's rice and wheat programme is one of the biggest and most diversified programmes in the world.

The main problem in the production of sorghum and other millets is the violent fluctuations in their production caused by the vagaries of climate.

Hybrids have been evolved using cytoplasmic male sterile line 'CK 60A' as female parent. In addition, some improved varieties have been released. All these hybrids and varieties combine shorter duration with high grain yield compared to the long duration low-yielding traditional varieties. The new varieties could do better in scanty rainfall years and not only impart stability to the production but also boost production.

The most significant achievement in pulses was the development of *Aschochyta,* blight-resistant chickpea, early maturing arhar, powdery-mildew resistant pea and yellow-vein-mosaic resistant green gram varieties.

The development of short duration varieties of moong, urd, cowpea and arhar has helped in increasing the area under these crops by fitting them in the various cropping patterns suited to the needs of different kinds of farmers in both irrigated and rainfed areas in the northern plains, Deccan and the southern deltas. It was thus possible to increase the area under pulses to the tune of about 15 to 20 lakh hectares.

Pulses research work which has been in progress for some years under the All India Coordinated Pulse Improvement Project of Indian Council of Agricultural Research helped in understanding the basic problems limiting pulse production and pointed out ways in which pulse production can be augmented.

Dryland Farming

Crop production in India's 110 million hectares of non-irrigated land can be tripled by introducing indigenous dryland farming technology. This hopeful picture on the agricultural front is further reinforced by experts' assessment. Some oil bearing crops can also be raised in non-irrigated areas thereby reducing substantially country's dependence on imports of edible oil.

Experts are of the view that the number of cash crops at least two in a year can be raised in areas where farming suffers not only due to lack of irrigation facilities but also due to paucity of power supply needed to energise pumping sets. In such cases, these areas can be turned into gold mines to yield cash crops like mustard raising incomes of the rural masses.

The new technology consists mainly of timely preparatory and seeding operations including conservation of stored soil moisture, use of improved variety of crops, establishment of adequate crop stands (population), satisfactory weed control and use of medium levels of needed fertilizers. Experiments have shown that the yields obtained with improved practices are several times higher than those achieved with common practices. The package of practices developed to conserve soil moisture includes deep tillage, surface cultivation and stable mulching.

Deep ploughing and subsoiling are usually effective in conserving moisture in the kharif season. The general objectives of deep tillage are to break plough soles and layers compacted by excessive implement traffic, impermeable soil horizons or other barriers to the movement of moisture and growth of roots through the soil profile.

In many unirrigated areas in India, repeated ploughing for centuries with the traditional plough has resulted in the growth of hard compacted layers below plough sole. This has restricted infiltration and movement of water and the penetration of roots. Subsoilers and chisel ploughs are suitable to break through and shatter hardened or otherwise impermeable soil layers. The chisel plough can break layers 25 to 35 cm deep. The subsoiler is effective up to 60 to 70 cm soil depth. Chisel ploughs and subsoilers are essentially tractor-drawn implements. The most effective results with subsoiler and chisel ploughs are obtained when the soil is dry. Under hard soil conditions the desired depth may be obtained by progressively increasing the depth of operation in repeated operations.

Proper choice of implements and their method and timeliness of operation are important for successful farming in unirrigated areas. The specific choice of the implements and their method of use would vary with the local requirements with regard to climate, soil and flora. The climate of many of the dry farming areas in India is characterised by corrosive winds during March to June, a period generally intervening between the harvest of the winter crop (rabi) and the sowing of the rainy season crop.

While deep tillage is considered beneficial to conserve monsoon rainfall, shallow working tools which cut beneath the soil surface without turning the filled layer is desirable for tillage operations during rabi. Surface tillage implements are used to till beneath the surface without turning the tilled layer. The tillage consists of operations which are parallel with the land surface to cut the weed, loosen the soil without major soil disturbance. Besides being effective in killing weeds and retaining a good part of crop residue on the soil surface, tillage implements are required to perform the initial tillage and prepare a satisfactory seed bed with a minimum of surface pulverisation.

Surface tillage implements consist of V-shaped sweeps or straight or curved blades, mounted on suitable frames. The age old implements like the *bakhar* or *guntaka* (blade harrow), commonly used in the dry farming areas in India, are effective in seed bed preparation and intercultivation. For intercultivation in flat sown row crop, full sweeps and half sweeps may be suitably arranged to match the crop rows.

Stable mulch farming is a planned system of tillage operations with crop residues to conserve soil and water. It was first used as a wind erosion control measure for cultivated land. The stables left on the surface of the soil protects the soil from the drop splash and wind.

Stable mulching is based on stirring the soil with implements that leave considerable part of the vegetative material, crop residues or vegetative litter on the surface as a protection against erosion and for conserving moisture by favouring infiltration and reducing evaporation. Stable mulch can be formed to surface sweeps or one-way disc harrows. The implements must be capable of cutting through heavy crop residues under favourable moisture conditions and leaving the residues well anchored and standing if possible. Repeated operations result in the covering of the vegetative matter and increased erosion hazard and evaporation losses. Seedbed preparation and planting are done in as few operations as possible. The planting equipment should preserve as much protective cover as possible and at the same time place the seed in firm moist soil to promote germination.

The seedling equipment for unirrigated areas are designed to place the seed in firm moist soil. The moisture in the surface layer of the seed bed in dry areas is evaporated quickly. Germination of seeds may be adversely affected if the seeds are sown at shallow depths of 4 to 5 cm. as in irrigated areas. However, the soil moisture at deeper depths may be sufficient for successful germination of seeds. Deep sowing with a conventional seed drill will result in too deep placement of seed and poor germination. Therefore, the requirements of seed drills for unirrigated areas are that it should make a furrow in the dry soil layer and place the seed in firm moist soil below the bottom of the furrow. The multi row seed drills with packer wheels (tractor-drawn and animal-drawn) are designed to obtain the optimum environment for the germination of the seed and growth of the seedling. The seed boots are designed to place the seed about 4 cm. below the bottom of the furrow made in the dry soil layer. Packer wheels fixed to the rear of the machine pack the soil cover the seed.

In the field of cropping systems, researches have revealed that crop production on drylands could be stabilised through crop diversification, intercropping of legumes in perennial desert grasses, and other dryland crops (bajra, mung, sunflower, castor) and recycling of runoff water in the event of drought. *Cenchrus ciliaris*, cluster beans and castor beans have been identified as potential crops capable of imparting stability to crop production on drylands. In a good rainfall year (500 mm) with an extended rainy season, double crop system of pearl millet followed by mustard was found to be the most remunerative.

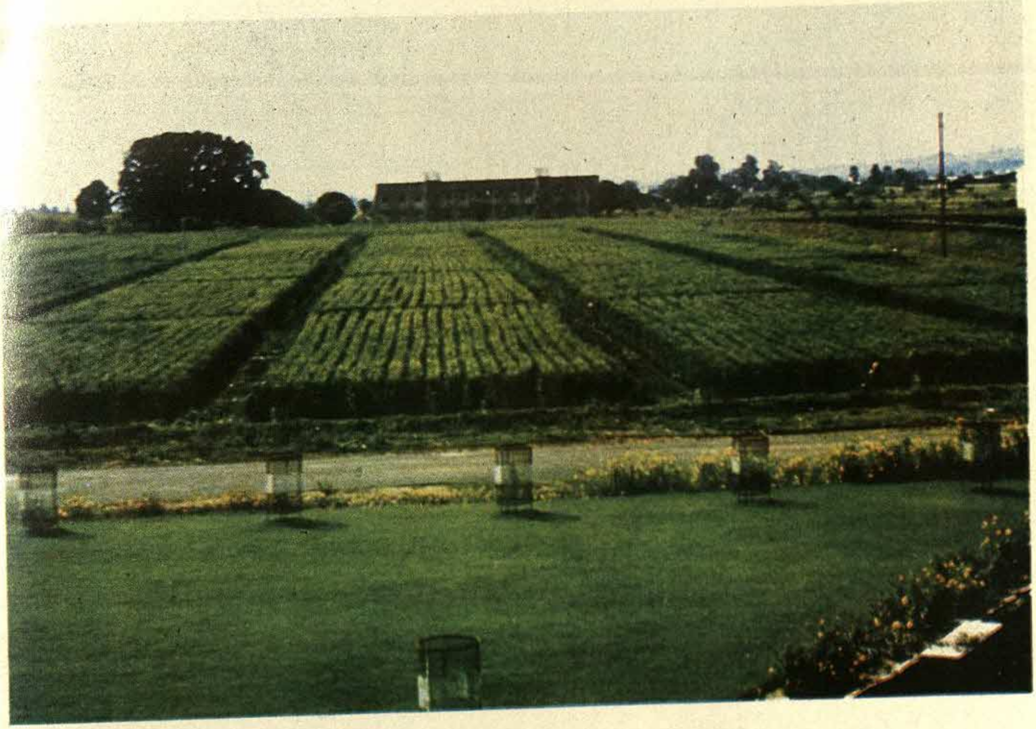
An innovative technology involving water harvesting from bare catchment, collection of runoff water in a pond, and recycling of run off water has been developed. Studies have indicated that runoff of the order of

15.8 to 26.6 per cent of the total rainfall could be harvested in good rainfall years. In the studies on interplot water harvesting (runoff farming), it was revealed that catchment to the cultivated area ratio of 0.5 each hectare of cropped area revives 23 to 100 mm of runoff as irrigation water from the catchment in addition to 117 to 528 mm from direct rain. The additional low tension water results in increasing and stabilizing crop yields, to mitigating the risk of crop yields, to mitigating the risk of crop failure, in saving inputs of production, and above all, in making the best of every rain drop that falls on the farm. A modification of the inter-row water harvesting system, by providing two micro-catchments instead of one, with a view to inducing more runoff, has been suggested. Dusting of wetted ridges, provided between two ditches in the Modified Inter-Row Water Harvesting System (MIRWH), with bentonite clay was found to result in inducing more runoff than the conventional inter-row water harvesting system.

Earlier studies revealed that stable mulching and wing strip cropping are the basic remedies for the maladies caused and accentuated by wind action. In an experiment conducted recently, a one metre wide strip of bajra (pearl millet) planted as a shelter barrier against the prevailing wind direction reduced the wind speed by 63 per cent and increased the yield of summer lady's finger and cowpeas by 190 and 90 per cent, respectively. To cut down losses owing to deep percolation a technique of partial moisture barrier incorporation, has been developed at the Central Arid Zone Research Institute, Jodhpur. The technique works very well when the barrier and runoff concentration systems are combined.

Out of 250-odd species introduced by the institute from a number of foreign countries, a few species of Eucalyptus and Acacia and a few others have been found to be extremely promising. Silvipastoral studies indicate that cultivation of sown pasture in the inter-rows of trees (5 m × 5 m) gave dry grass yields ranging from 700 to 2,000 kg/ha without affecting tree growth. Lopping schedules of top feed species such as *Prosopis cineraria* and *Zizyphus nummularia* have been standardised. *Eucalyptus virdis* have been found to be most promising in respect of oil. So also an exotic species from Arizona, viz. *Simmondsia chinensia* (jojoba) for wax.

Silvicultural studies indicate that a leguminous tree *Dichrostachys glomerata*, an introduction from Israel which is not only quick growing but is extremely hardy and resistant to drought and frost is very suitable for introduction in Indian arid zone. It spreads itself by throwing sucker and its leaves can be used as fodder and are highly nutritive. Similarly, *Dichrostachys mutans* which also regenerates well naturally holds a great promise for stabilisation of sand dunes and reclamation of land slides and ravines.

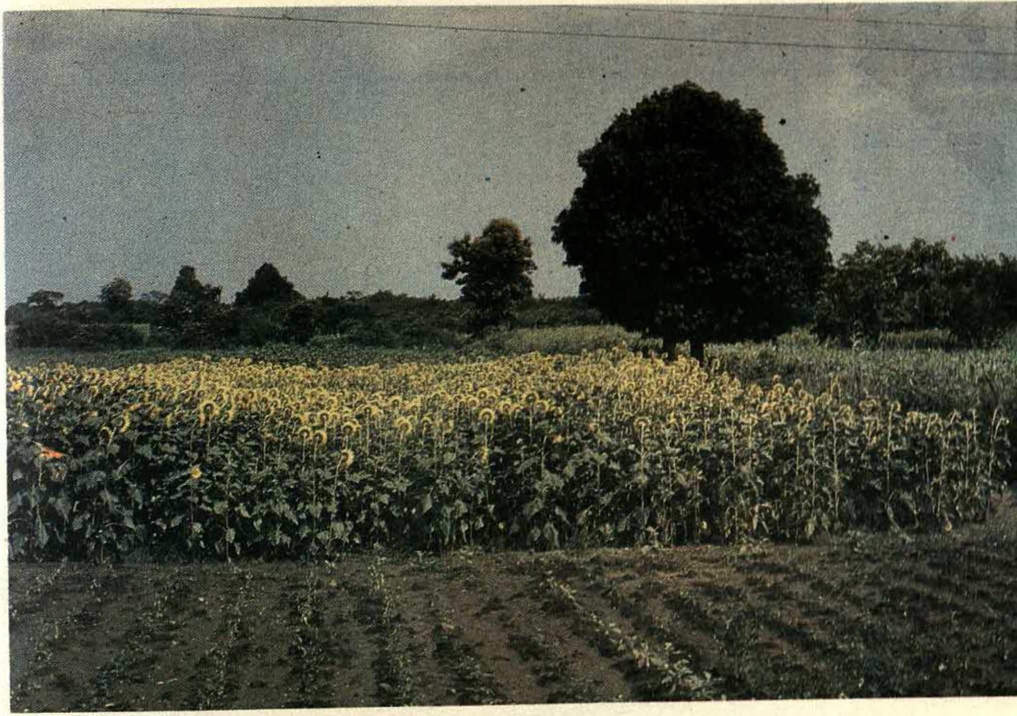


A View of Modern Farm

High-yielding Rice Varieties

High-yielding Wheat Varieties

Green House



High-yielding Mustard Variety Growing in Field

New Variety of Rose

Colophospermum mopane introduced from South Rhodesia has self-regenerated profusely from seed dispersal under arid conditions. Further studies of this species are in progress. Energy plantations fit well into the requirements of less intensive land use of marginal and submarginal lands. *Acacia tortilis, Azadirachta indica, Prosopis juliflora, Acacia nilotica* and *Albizzia lebbek* have been identified as promising plantation species for supply of fuel supplementation in rural arid areas. Economic analysis is very much in favour of *Acacia tortilis.*

Wind erosion is one of major hazards in arid zone especially for agriculture. So one of the important techniques to control the spread of desert conditions is afforestation including establishment of wind breaks and shelter belts to provide mechanical obstacle to the free sweep of wind so as to reduce its velocity. Another important measure in this direction is the stabilisation of shifting and dunes, over 1,000 hectares. Experiments to find out the suitable design and tree species for effective wind breaks are being conducted. Measurements on wind reduction at different distances, micro climatic changes and effects of these belts on crops yields and dust movement are being carried out.

Diosgenin, which is as important raw material for the production of steroid harmones and oral contraceptives, has been isolated (1 per cent yield) from *Balanites roxburghii,* an indigenous plant in rocky and semi-rocky areas. A wax, commercially known as Candelilla wax, has been isolated (in 2 per cent yield) from *Euphorbia antisyphilitica.* This wax is used in the manufacture of explosives. The fruit crops suitable for the arid zone environment have been identified under dryland conditions, with suitable water harvesting for (*Zizyphus mauritiana*), pomegranate (*Punica granatum*) guava (*Psidium ghuajava*) custard apple (*Annona squamosa*) can be successfully grown. With supplementary irrigations sour lime (*Citrus aurantifolia*) and Amla (*Emblica officinalis*) may be grown. Under the conditions of assured irrigation facility, fruits like mulberry, phalsa, grape, date-palm, sweet oranges and papaya can be grown profitably. Detailed cultivar evaluation with respect to ber and data-palm and evaluation of suitable water harvesting system for growing of ber fruits are in progress. An improved technique for establishing ber orchards has been developed.

As a result of research carried out for several years at various institutes, improved practices for raising the productivity of waste lands have been identified. It has been recognised that because of heavy livestock pressure, it is not possible to have a successful waste management programme without proper fencing. Angle-iron posts with a fencing of barbed wire costing around Rs. 9 per running metre, is by far the most effective and economic means in the long run. Unwanted thorny plants should be grubbed out mechanically followed by the application of the herbicide 2-4, 5-T immediately after putting away the aerial parts of the bushes. With a view to improving livestock production, providing shade for grazing animals and the top-feed during the lean periods, it is imperative to introduce some suitable top-feed tree species. A good pasture may have about 30 such trees per hectare.

Soil conservation measures increased the forage production significantly. The average increased yields, as a result of contour furrowing, contour bunding and contour trenching, were of the order of 638.7, 168.8 and 165.0 per cent respectively per year. Contour-furrowed plots were found to contain more available soil moisture than contour bunded or contour-trenched plots.

A technique of reseeding the grasslands has been perfected. The technique consists of selection of suitable species for different agro-climate regions, reseeding the mixture of *Cenchrus* species and *Lasiurus sindicus,* and *Cenchrus,* species and *Dichanthium annulatum* in low and high rainfall areas, respectively, at the rate of 5-7 kg/ha and drilled uniformly in rows spaced at 75 cm apart in furrows 8-10 cm deep at a depth of 1-3 cm, and two weedlings done during the first year of establishment.

Several high-yielding varieties of maize, wheat, barley, mustard, bajra, gram, sorghum, urd, castor, have been developed in the country. Besides, alternative crops have been identified in case there is a progressive delay in the monsoon. If the rains are late by about two weeks only, shorter duration varieties of the normal crops could be used. When rains are further delayed, choice of crops suitable for late sowing has to be made. The choice may successively fall on sorghum, castor, pigeon pea, pearl millet, rice, maize, ragi, groundnut, cowpea, setaria or horse gram depending on region and soil. Experts are of the view that timely sowing is one of the most important agronomic inputs that determines the success of dryland crop.

Not much can be done when the monsoons cease earlier than normal. Use of short duration varieties of crops will be helpful in regions where early cessation of rains are frequent. Deep rooted crops (pigeon pea or castor) also sustain themselves better on moisture in the deeper layers of profile.

Dairy Technology and Animal Husbandry

In India livestock sector, cattle and buffaloes occupy a pivotal position in the national economic development. The country has not only the world's largest population of cattle, but also has some of the best breeds of cattle and buffaloes.

Cow and cow-keeping have been accorded a sacred place in India since ancient times. The country has a rich heritage of cattle breeds, outstanding for drought qualities and dual-purpose (drought and milk). The Indian zebu cattle is renowned all over the world for its relatively higher resistance to tropical heat and diseases. India's bovine population comprises 180 million buffaloes. Although majority of them do not conform to any descript type, some 20% of them belong to 26 cattle breeds and 7 buffalo breeds. Although dairying has been part of life in India since the ancient Vedic times, the modern dairy industry took roots in 1950 with the sale of bottled milk in Bombay from the Aarey Milk Colony. Before that, raw milk without any processing was being supplied all over the country at the consumer's door in the traditional way.

Since 1950, the total expenditure on dairying in all the six plan periods up to 1983-84 amounted to Rs. 6,613 million. In the Seventh Plan the proposed outlay is Rs. 3,950 million and aims to achieve the target of 52 million tonnes of milk production by 1989-90, the last year of the plan, which will provide per capita availability of 165 gm of milk per day.

There are about 24 agricultural universities, including seven dairy science colleges and 22 veterinary colleges, which provide the base for education, extension, research and training as well as provide the infrastructure to meet the wide-ranging requirements of manpower for the rapidly growing dairy industry. Apex organisations include the National Dairy Research Institute (NDRI) (established in 1923), the Indian Veterinary Research Institute (IVRI), (established in 1889) and the National Dairy Development Board (established in 1965). A Central Institute for Research on Buffaloes has been set up at Hissar in Haryana. A Bureau of Animal Genetic Resources has been established in Bangalore to undertake surveys for identification, description and evaluation of indigenous germ plasm resources and to ultimately undertake conservation of the native cattle germ plasm, noted for its higher resistance to tropical heat and diseases.

To facilitate undertaking major research projects under diverse agro-climatic conditions, the Indian Council of Agricultural Research (ICAR) has sponsored seven All India Coordinated Research Projects. They cover the breeding of cattle, buffaloes and goats as well as studies on foot-and-mouth disease (FMD), utilization of agricultural byproducts. The ICAR is also setting up two biotechnology centres, one at IVRI, Izatnagar, and another at NDRI, Karnal, to develop the technology of embryo transfer in immunoreproduction. Various efforts are under way to facilitate transfer of appropriate technology from operation research project (ORP) of the National Dairy Research Institute.

Two new high-yielding strains of dairy cattle—Karan Swiss and Karan Fries—have been developed at the NDRI, Karnal. Similarly, a large crossbred population involving Brown Swiss, named Sunandini, has been evolved in Kerala. These superior dairy breeds have been evolved by crossbreeding indigenous cattle with superior exotic dairy breeds.

The All India Coordinated Research Project on Cattle has been working on the development of cross-breeding technologies for evolving new dairy breeds to suit different agro-ecologies. Projects for systematic production of progeny-tested crossbred bulls are in operation in the states of Kerala, Punjab and Assam. Under this programme, Brown Swiss, Hostein-Friessian and Jersey crossbreeds are evaluated for their breeding values in the field conditions and made available for extensive use in cattle development programme. The Seventh Plan approach to breeding research emphasizes study on the genetic aspects of production of crossbreeds and the development of systems of progeny testing as well as actual testing. The multiple ovulation embryo transfer technology for speedily increasing the population of elite cows has been tried successfully.

A network of over 30,000 veterinary hospitals, dispensaries and aid centres have been set up to provide free of cost veterinary health care. Veterinary biological institutions produce annually 380 million doses of vaccines against a number of communicable diseases. A wide range of veterinary medicines and biologicals, including vaccines for major disease are produced in the country at the IVRI, state veterinary biological laboratories and private commercial organisations. A 25-million dose capacity plant for foot-and-mouth disease (FMD) vaccine has been recently commissioned at Hyderabad by the Indian Dairy Corporation's subsidiary, Indian Immunologicals. A network of disease diagnostic centres are in operation in the country. In addition, there are more than 500 mobile veterinary clinics run by cooperative societies/federations to provide animal health cover in 96 milkshed districts under Operation Flood.

For the control of FM, a quadrivalent inactivated vaccine, using 'BMK-21' cell culture and aluminium hydroxide gel, is being produced. Its present annual production of about 10 million doses in four laboratories can be raised to more than 50 million doses, the installed capacity. The present strategy is to give prophylactic vaccination to all valuable and crossbred animals. To the small farmer, a 50% subsidy is allowed so that he gets it at half the cost. In the case of an outbreak, ring vaccination is carried out free of cost to prevent further spread. Research in the field of livestock health would lay emphasis on developing systems of surveillance and monitoring so that disease outbreaks could be forecasted and suitable prophylactic measures undertaken.

Today, the country has attained self-reliance in dairy equipment in almost all aspects. The total annual demand for dairy equipment in India increased from Rs. 230 million in 1970 to Rs. 450 million in 1980, and the quantum of imported equipment dropped from a level of 60% of domestic demand to barely 10%. Now, some 130 enterprises, including five in the public sector, are meeting most of the requirement for the processing plants as well as in the cryogencies. Notable gains in recent years include sophisticated equipment like electronic milk packaging for long shelf-life and milk vending units.

The range of milk processing and packaging equipment manufactured in the country include : batch pasteurizers of up to 2,000-litre capacity, 'HTST' pasteurizers up to 20,000 lph (litres per hour), automatic bottling plants including bottle washers, fillers, cappers and conveyors up to 10,000 litres; cheese and conveyors up to 10,000 litres or 20,000 bottles per hour capacity, ghee boilers up to 1,000 litres; cheese and casein vats up to 5,000 litres; packaging equipment for butter and ghee in tins; cheese vats and presses; ice cream freezers; multiple-effect evaporators; vacuum pans; lactose crystallizing vats spray dryers and homogenizers of small capacity up to 100 litres per hour.

In the field of cattle feed, the Indian Grassland and Forage Research Institute (IGFRI) is contributing significantly to the evolution of varieties of cultivated fodders, grasses and legumes which are high in yield and have input responsiveness and disease resistance. The institute has identified a number of non-conventional feeds for livestock as well as developed process for chemical treatment of low-quality roughages for improving their nutritive values. The seven Regional Stations for Forage Production and Demonstration and the Hessarghatta Fodder Seed Farms produced over 3,000 quintals of foundation certified seeds. In the coming five-year plan period, nutritional research would emphasize developing feeding systems based on existing feed resources, specially under farmer's conditions. Animal feed security systems would be developed to meet the requirements of livestock in famine and flood-prone areas. Research would also be intensified in the area of microbial degradation of agricultural and animal wastes, specially the lignocellulose and utilization of fallen animals and slaughter house byproducts.

Research also helped to establish methods of treatment for purposes of detoxification, improving palatability and digestibility of raw materials. With continuing upgradation of livestock, the feed industry has ably kept pace on optimising feed formulation to continuously meet the increasingly nutritional requirements.

The world's largest dairy development programme, 'the Operation Flood,' undertook the task of upgrading and modernizing milk production, procurement, processing and marketing with assistance provided by the World Food Programme, the European Economic Community (EEC), the World Bank and other agencies. Designed and implemented by the National Dairy Development Board (NDDB) and the Indian Dairy Corporation (IDC), the project was launched in July 1970. Its basic concept comprises the establishment of milk farmers' cooperatives. The Operation Flood (OF) I ended in June 1981 with an investment of Rs. 1,160 million, benefiting 1.5 million rural families, banded together in 12,000 village cooperative milk producer societies in 27 selected milkshed districts, paved the way for an expanded programme (OF-II) with an additional investment of Rs. 7,800 million, covering 155 milkshed districts and linking them to markets in 147 towns and cities benefiting 10 million rural families. The future prospects for dairy development appears to be bright as the annual growth in the milk production in the Seventh Plan is envisaged at 6.8% as against 1.1% in 1951-56.

The need to exploit female's participation in herd improvement and genetic conservation initiated the Multiple Ovulation Embryo Transfer (MOET) experiments in cattle. Recent success in developing non-surgical techniques for embryo recovery from the donors, their cryo-preservation in India and abroad has revolutionised the concept of cattle breeding.

The technique is used to increase the number of calves in the reproductive life span of a chosen cow. This is essentially achieved by creating larger number of ova shed each cycle than happens normally and transferring this at early embryonic stage of development, into other cows to complete the gestation period.

In India, the Department of Science and Technology and ICAR have decided to establish centres of biotechnology. The ICAR is setting up two centres, one at IVRI, Izatnagar, and another at NDRI, Karnal. The main emphasis would be to develop the technology of embryo transfer in buffaloes to accelerate genetic improvements. These centres in turn will be able to transfer this technology at organised breeding farms and finally to the farmers, to revolutionise the production of better buffaloes for higher production.

It will help exploit reproductive performance of bull mothers. They would make the largest contribution in buffalo milk production. This will also help in preserving the better germplasm and could slow down the genetic drain which at present is destroyed by the dairy farmers of large metropolitan cities.

Research in animal husbandry has been stressed in the Sixth Five-Year Plan mainly on achieving higher productivity through genetic improvement of animal health and better mutation and dairy technology.

As a result, emphasis is placed on selective breeding in some tracts of indigenous breeds and similar methods made in other cattle species has resulted improved strains like Karan Swiss and Daran Fres in cattle Avikal in and Avivastra carpet wool strain of sheep, ILI-18 and IBL-18 strains for broiler and layers in poultry. Buffalo breeding is likely to make greater strides through a recent perfecting of the semen preservation technique. Animal health has received greater attention since a variety of diseases like pests affects the livestock. Tissue culture vaccine against foot and mouth disease of cattle, goat disease vaccine for rinderpest, and oil-adjuvent vaccine for haemorrhagic septicaemia of cattle and buffalo are some of major advances in Indian veterinary research.

Vaccines have also been evolved for lung worm diseases in sheep, swine fever in pig, and Ranikhet and Marek's disease in poultry. In the dairy technology, new processes have been developed for production of different milk products, detection of adulteration, extraction and purification of rennet used for production of cheese, and prevention of oxidation of milk and its product.

Fisheries

Work in fisheries in India is focused on evolving suitable methods for their conservation, management and development and the major achievements in this area include introduction of induced fish breeding technique using the pituitary gland injection for producing fish seed, establishment of a miniature 'Pituitary Bank', development of advanced technology for culturing prawns, mussels, eels and natural pearls.

A method of extraction of agar from seaweeds without using either freezing or other equipment to purify agar at the jel stage has been developed by the Central Marine Fisheries Research Institute. Methods have also been developed for the extraction of algin.

Another impressive achievement is the successful development of technology of production of cultured pearls using entirely indigenous material and know-how. The work carried out on saltwater fish culture has shown that the production of milkfish in saline lagoons and the saline ponds can be substantially increased by proper management procedure.

Culture methods for other fin fishes such as Mullets, Sillago, Etroplus have also been developed. A method of culturing eels in running water has been developed which could give a production of 38,000 kg/ha at the end of two years. Cultivated young eels have a good market and are in great demand in countries like Japan. Intensive investigations on the large scale culture of prawns have made it possible to breed in captivity and the larvae thus obtained have been reared to juveniles.

Significant advances have been made in the development of designs of trawl nets for operation from trawlers of various sizes. The operation of these have enabled an increase in the prawn, fish catch per unit. Design and development of gill nets for catching lobsters and frame nets for operation in reservoirs, trawl lines for the capture of predatory fishes and purse sein for the exploitation of pelagic fishes are other contributions made in the field of fishing gear. Improvements of the indigenous fishing gear and methods for fishing in the Brahmaputra river system have been worked out and suitable fishing gear and methods have been evolved for fishing in Sunderbans and in Bheels.

Design of mechanized fishing boats suitable for operation along the Indian coast taking into account the specific conditions of the fishery in different regions have been prepared by the Central Institute of Fisheries Technology (CIFT). A number of mechanical fishing accessories, ancillary fishing equipment and electronic testing device have been designed by the institute. Particular mention may be made of a power-isolation clutch for power transmission from the engine of the winch, gallows, jockey, pulleys, mechanical spraying arrangement for chumming of fish, impulse generator for carrying out electrical fishing, a telemetry type electro-mechanical net depth meter for continuous measurement of the depth of operation of the trawl net.

Methods have been standardized for canning of prawns, sardine-mackerel, tuna, seer, lactarius, tilapla, mirror carp, silver pomfret, clams, mussels, smoked eel and catfish. A process has been developed for processing shark skin into good quality leather and methods have been worked out for production of shark fin rays, fish maws and good quality fishmeal from sun-dried fish. Methods have been standardised for the long distance transportation of fresh fish and suitable containers have been designed and developed for the purpose.

The advances made in fresh-water aquaculture in the country include the development of technique of induced breeding by pituitary hormone, administration of the Indian major carps and Chinese carps which enables them to breed in captivity in ponds and thus paving a way to produce seed of desired fish in pure form at the pond site, the development of technique of bundh breeding of grass carp and silver carp which opens a new avenue for the production of their seek on a large scale, the development of a package of practices, known as Composite Fish Culture, involving pond fertilization, manuring and artificial feeding for obtaining high fish production from stock ponds.

Considerable improvements have been effected in breeding and rearing browns and rain-bow trout and mirror carp, the two principal fisheries of the cold-water of the country. Artificial feeds for trouts have been developed to enable commercial production of the fish in farms.

Grain Storage

Several foodgrain storage technologies to protect cereals from insects, pests, moisture and birds have been developed by Indian scientists. These save the country at least 15 million tonnes of foodgrains lost every year for lack of proper storage facilities.

Over a dozen research institutions in the country have developed over 40 designs of indoor and outdoor bins of various capacities, suitable to different agro-climatic conditions, using different materials and techniques for storage of cereals. Various chemicals have also been developed for fumigation purpose.

The Indian Grain Storage Institute, Hapur, has developed over 30 designs of bins of different capacities ranging from 0.31 to 15 tonnes. The storage structures could be constructed by using wide varieties of locally available materials like paddy straw, split bamboo reeds, mud and bricks. Advantages in scientifically constructed bins are that they are free from damp and rodent and bird proof. It is also much easier to carry out fumigation in such bins. Besides, they are more economical than traditional bins where dampness is a constant source of trouble, fumigation is seldom possible and cross infestation cannot be entirely eliminated.

Scientific designs have been developed and constructed for bagged storage of cereals where damage by rodents and dampness has been practically eliminated. Fumigation has been rendered possible which has made the control of insect pests easier and more certain. Various designs like shell type roofing, tubular trusses, precast concrete portal frames, welded space trusses, steel trusses and even timber trusses have been evolved to make use of the local materials that are available.

Bulk storage is most suitable for storing grain like wheat for long periods. The costs of preservation are substantially lower and it is possible to utilise facilities for mechanical handling which are both cheap and efficient. A grain elevator or a silo provides the best form of storage. In its simplest form, it consists of a head-house which lifts the grain and a number of circular bins into which the grain is then transferred for storage. It not only preserves the grain for many years, but also keeps it in good condition. There is no discolouration of grain. Its appearance and marketability remain unaffected. Handling is easy and the problems of fumigation and drying are greatly simplified. For the port areas, it possesses the additional advantages of maximum storage in a given space and quick discharge of ships resulting in lower freight, savings in port charges, and avoidance of ship demurrage. The port's capacity to handle ships is also thereby increased. It is, however, a costly form of construction—about Rs. 400 per tonne capacity.

The design to construct another form of bulk storage called flat storage has been developed in the country. It not only possesses many of the advantages of the silo, but is also cheaper to construct. Grain can be stored in flat storage for three to four years without any need for turnover. Fewer fumigations are required than for grain stored in a conventional godown. The areas of infestation can be quickly located with temperature recording equipment and remedial action taken. The equipment required is less sophisticated than for the silo and a substantial part of it can be manufactured within the country.

Scientists of the Indian Agricultural Research Institute, New Delhi, have developed various kinds of bins namely Pusa bin, Pusa cubicle and Pusa Kothar. The structures are an improvement brought by incorporating such features as essential for safety of grains. It is further supplemented with variability in storage capacity by modifying in size and design. While Pusa bin could hold grain from 1 to 8 tonnes, meeting the demand of cultivators, Pusa cubicle and Pusa Kothar serve the warehouse. In Pusa cubicle grain or seed could be stored in bags also where identity of different varieties is possible to maintain.

In a situation where such methods could not be utilised simple modifications in conventional devices can impart safety to produce in storage. Dunnage of polythene sheet or wooden frame under bag covered by polythene sheets at the bottom and top of metal or concrete circular barrels provide moisture proofing. Sandwitching of polythene sheets on the floor of room meant for storage are a few methods which are not costly.

Rodent proofing of storage structures and premises involve raising of plinth to IM rodent proof foundation and check on access of rodent by removal of support. Fixing of 24 gauge thick 30 cm wide metallic plate on door facing floor and bottom of windows also provide rodent proofing. Rodent population can be brought down by using 2 per cent zinc phosphide or 0.02 per cent anticoagulant compound. Cheap grain and grain products are used as base for the baits, small quantity of grain or seed stored in pitcher can be protected by covering from top with 5 cm thick layer of fine ash or clay. Pusa seeds coated with mustard or coconut oil check damage.

Muslin or closely woven jute cloth bag or polythene of 700 gauge restrict entry of pulse beetle. Infestation arising out of old or new sources develops quickly and causes damage to the stored products. A regular prophylactic spray schedule can keep down infestations.

Soil Reclamation

The soil salinity and alkalinity are factors restricting economic and efficient utilization of available land resources and adversely effecting crop production especially under arid and semi-arid conditions in India, the problem of salt-affected usar soils is primaeval and afflicts wide tracts to the extent of about 7 million hectares in different parts of the country. It has been noticed that these soils occur usually in association with normal soils in small patches or in big contiguous blocks.

Although the problem of soil salinity/alkalinity in India has been very old, the real efforts to reclaim such areas on a field scale have been very few and that to only in the recent past. Since the reclamation procedure is location-specific, generalization of any technique is not desirable specially when the conditions differ so widely. Successful reclamation involves a package of practices suited to the nature and problem of soil, quality and depth of ground water, calcareousness of the soil, physical condition of subsoil, availability and economics of the ameliorative measures and such other associated factors. In general, the various methods of reclamation can be grouped into (i) Chemical, (ii) Agro-technical, (iii) Biological and (iv) Hydro-technical including engineering aspects.

During the last few years, after the establishment of the Central Soil Salinity Research Institute, in Karnal, the scientists carried out a series of experiments on reclamation of the salt-affected soils including new methods of reclamation, crops and varieties, fertiliser requirements, water management for the reclamation of sodic soils.

Reclamation of sodic soil: Some of the essential components of this 'package' are (i) proper bunding and land levelling, (ii) application of suitable amendments in right quantity and right manner, (iii) adequate application of fertilizers and manures along with zinc application (iv) choice of proper crops and varieties and cropping sequence (v) use of appropriate cultural and agronomic practices, and (vi) proper water management.

Chemical: For the reclamation of alkali soils many inorganic amendments are in use, some are sources of calcium such as gypsum, while others are either acids or acid forming materials. Like sulphuric acid, sulphur and iron pyrites. The latter are effective on calcareous soils as they solubilize native calcium for further reaction. In most cases reclamation of alkali soils involves replacement of sodium on the exchange complex with calcium and improvement of physical conditions of the soils. The choice of an amendment is governed by many considerations such as its availability, ameliorative effect, cost, ease in transportation, storage, handling and application. Certain chemical amendments are costly and not available easily in required quantity or their use involves complex technical skill, and therefore, their application has been largely on an experimental level. Among the various amendments gypsum is by far popular and is frequently used on a large scale in many countries. The beneficial role of gypsum in the amelioration of alkali soils has been reported by several workers in India.

Extensive deposits of gypsum exist in the arid region of Rajasthan near Bikaner, though some deposits also occur in parts of Gujarat, Tamil Nadu, J&K and Uttar Pradesh. It is necessary to determine the minimum quantity of gypsum that is required for improvement of an alkali soil, so that the use of this amendment can be within the resources of the farmer without sacrificing the success of reclamation. On the whole, the dose of gypsum application depends upon the nature and degree of deterioration of the soil, physical and other properties of the soil, the depth to which soil is to be reclaimed, the extent of improvement desired and kind of crops to be grown. In this context, it was considered appropriate to reclaim initially only the surface 0-15 cm soil, so that shallow-rooted and tolerant crops like rice, wheat and barley, could be grown. This approach helped in reducing the dose the amendments to a considerable extent. The results of a field experiment conducted at the Central Soil Salinity Research Institute's (CSSRI) research farm indicate that application of gypsum at a rate equivalent to 1/4th of gypsum requirement is adequate to improve the conditions of a highly deteriorated sodic soil for obtaining good yields of paddy, wheat and barley crops.

In field experiments conducted on a sodic soil, (pH 10.3 and EC 9.45 mm hos/cm) at CSSRI, best results in case of shallow rooted crops like barley, rice and wheat were obtained when gypsum was mixed only in surface 10 cm soil depth. Mixing of gypsum to great depths was found to be less effective. The work done at CSSRI, Karnal, has shown that application of gypsum only once in the beginning is adequate to achieve the desired results provided all other necessary management practices are followed.

Phospho-gypsum, a byproduct of phosphoric acid manufacturing plants, is reported to have 80-90 per cent purity as a source of Calcium Sulphate ($CaSo_4$) and can be used for reclamation of sodic soils. It has been found at CSSRI, Karnal, that byproduct phospho-gypsum is a promising amendment.

Agro-Technical Methods

Agronomic and cultural practices: Coming to the problematic nature of salt-affected soils, the agronomic practices have to differ from those recommended in normal soils. The various agronomic and cultural practices for alkali soils have been worked out in detail at the Central Soil

Salinity Research Institute, Karnal. Proper land levelling and bunding is essential to achieve uniform water application, effective leaching, greater reaction of amendments, better fertilizer use, more uniform crop growth for speedy reclamation. Pudding of soil which is an important practice in rice cultivation is a harmful practice in the highly impermeable sodic soils, especially in the beginning of the reclamation process. Scientists have shown that owing to higher mortality and lower tillering under alkali conditions, an increase in plant population from 2 to 4 seedlings per hill resulted in significantly higher grain yields of rice. Further, older seedlings of 5-6 weeks gave higher yield than the younger seedlings and early transplanting done from the last week of June to about the second week of July in case of dwarf high-yielding and medium duration varieties like 'IR-8', 'Jaya', etc. gave significantly higher yields than those of the late• transplating.

Choice of crops, varieties and cropping sequence: Since crops differ considerably in their tolerance to soil salinity/alkali conditions, rational selection of suitable crops, their varieties and cropping sequence depending upon the stage of improvement of soil is of paramount importance in the reclamation programme. Scientists have proposed a salinity-cum-alkali scale to evaluate the saline soils of Indo-Gangetic Plains for crop response. For sodic soils, rice-wheat rotation has been recommended. If sufficient irrigation water is available during summer months, growing of dhaincha (*Sesbania aculeata*) as a green manure crop after wheat, may be beneficial. Inclusion of rice crop in the rotation has been found to be very helpful in reclamation of alkali soils, because of its relatively greater adaptability to the alkali conditions and its remarkable effectiveness in bringing about considerable reduction in pH-and ESP values of the soil.

Screening of several varieties of important crops has been carried out at the CSSRI for their tolerance to varying levels of soil salinity and alkali conditions. In case of rice, amongst the late maturing groups, varieties like 'IR-8' and 'Jaya' and among the early maturing group, variety 'Pusa-2-21' have shown superior performance than others in alkali soils. In case of wheat crops, varieties, 'HD 1982', 'WH 157', 'WL 711', 'HD 1553' and 'HD 2009' have been found to do better in soil alkali conditions than others. In case of barley, varieties 'DL-70', 'DL-36', 'BD-105', 'K-153', 'K-198', and 'BHS-24' have outyielded the other varieties included in the trial. In the evaluation of field trials of sugarcane varieties, 'CO 1148', 'CO 975' and 'B 37172' have done better than others on partially reclaimed sodic soils. In sugarbeet variety 'Maribo resistapoly' has shown better behaviour on sodic soils. Among the oilseed crops *Brassica, juncea* has given satisfactory performance. Physiological basis of salt tolerance of various crops and varieties has also been examined in detail. Striking differences have been observed among the varieties with regard to NA^+ and K^+ content in the leaves under conditions of varying soil ESP levels. Relativelv higher Na^+K^+ ratio has been observed in the more sensitive varieties. After critical evaluation of various parameters, it has been found that slope of the regression line can be considered as a criterion for judging the salinity tolerance of a particular crop.

Water management: In highly sodic soils, proper water management merits great attention particularly in case of wheat crop as heavy irrigations adversely affect wheat crop. The work at the CSSRI has revealed that light and frequent irrigations result in better growth of wheat crop, though the total quantity of water used remains the same. Sprinkler method of irrigation has been found helpful in achieving light and frequent irrigation, in lowering salt concentration in upper soil and in increasing crop yield on partially reclaimed sodic soils.

Mulch: The use of waste material of rice husk as mulch in sodic soil has been found useful for improving the soil condition and increasing paddy yield. Researchers in a field experiment on a sodic soil and CSSRI research farm have observed that addition of 20 to 30 t/ha of rice husk in upper 10 to 12 cm soil resulted in a significant improvement in the infiltration rate and in increased paddy yields. The beneficial effect mixing rice husk along with gypsum in increasing paddy yield on farmer's field has also been observed.

Manures and fertilizers: The beneficial effect of fertilizers and manures on the salt-affected soils has been noticed by several workers. The work done at the CSSRI, Karnal, has shown that an increase in the dose of nitrogen by about 20 to 25 per cent as compared to normal soils benefits the crops. Experiments to find out the appropriate method of application of nitrogenous fertilizers to soil have shown that in case of rice and wheat crop, it is better to apply half the dose at sowing and the rest in two equal parts at three and six weeks age. In experiment on foliar v/s soil application of urea at 28 kg N/ha, in two sprays, i.e. 10 kg N/ha at a time, was at par with 60 kg N/ha through soil. Amongst nitrogenous fertilizers ammonium sulphate has given better results as compared to either urea or calcium nitrate.

To effect economy in fertiliser use in rice-wheat rotation field experiment comprising several NPK combinations was initiated with rice during kharif, in 1974. In both crops taken in succession for 3 years, it was observed that by missing application of both P and K there was no reduction in yield of either crop when compared to nitrogen application alone. However, further studies are in progress to evaluate the response of P to these crops, especially wheat. Deficiency of available zinc is a common feature in alkali soils and therefore, application of zinc sulphate has been found to be beneficial. Experiments have shown that application of zinc as zinc sulphate increased the yields of crops like rice and berseem as compared to no-zinc application.

Biological methods: The reclamation process of salt-affected soils is enhanced and continued further if suitable biological methods are also followed simultaneously. The biological methods included green manuring, growth of trees, grasses and agricultural crops, addition of organic materials, etc. Although the use of biological methods in the reclamation programmes has received attention for long, scientific data regarding the changes brought about in the soil are very meagre.

Green manuring: Of the various crops used as green manure, dhaincha (*Sesbania aculeata*) had proved most useful. Green manuring with *Sesbania aculeata* was found to enhance the reclaiming effect of gypsum and to enrich the soil with organic matter and nitrogen besides improving the permeability of alkali soil.

Addition of organic materials : The application of farmyard manure, molasses, pressmud, paddy straw has been used in the reclamation of salt-affected soils. In the experiments conducted on a sodic soil (pH 10.5 and ECe 10.7 mmhos/cm) at CSSRI, Karnal, significantly higher yield of berseem and paddy grown in succession were recorded in the treatment having application of both gypsum and FYM than the treatment having either of the two.

Grass growth: The work done at the CSSRI has shown that Para grass (*Brachiaria mutica*), Bermuda grass (*Cynodon dectylon*), Blue, plachne fusca have shown good promise on sodic soil even in the absence of addition of any amendment. Their relative performance at different levels of soil alkali conditions has also been examined at the CSSRI. Although the beneficial role of grasses in improvement of sodic soil has been reported by many workers, the exact data regarding the changes brought about in the soils are very meagre and this calls for details studies under different conditions.

Tree growth: Tree growth is reported to exert ameliorative effect by improving physical, chemical and biological properties of the soil. In a field experiment initiated in 1970 on a calcareous sodic soil with pH above 10.0 and EC ranging from 0.45 to 1.75 mmhos/cm (1.2 soil water suspension) after treating the soil with gypsum at 50 per cent of GR+FYM in the planting pit was almost as good as in the original soil replaced with good soil. Most of the planted seedlings died in the control. The height of plants increased further with fertilizer application. *Prosopis juliflora* showed almost similar performance. *Acacia arabica* is a slow growing species, but it is likely to show satisfactory growth performance over a long period.

Terminalia arjuna and *Albizia lebbek* could be grown only on mild soil alkali conditions.

Hydro-Technical Methods

Leaching: Leachings of salt-affected soil with water has been used as a measure for reclamation in many places. However, in areas which have problem of soil alkalinity, leaching along with application of amendment like gypsum will be more effective. Studies have been conducted at the CSSRI, Karnal, to determine the relative efficiency of intermittent and continuous ponding and gypsum application in highly deteriorated sodic soil. The results show that leaching in combination with gypsum application is more efficient in the sodic soils. More detailed studies are required to determine the period, extent and method of leaching which may be most suitable under a given set of conditions.

Drainage: The drainage requirements of the salt-affected soils are location specific and vary according to the local conditions like extent and nature of deterioration, soil texture, hydraulic conductivity, depth of groundwater. The drainage needs are of great divergence in case of sodic and saline soils. The drainage and hydrologic aspects of salt-affected soils with and without reclamation have been studied in great detail at CSSRI, Karnal. The sub-surface drainage in the sodic soils of Indo-Gangetic Plains which have poor water transmission characteristics as noticed at the CSSRI Research Farm is not effective and therefore, proper manipulation of the excess rain water alone could yield good results. About 60 per cent of the total rain water can be stored in the bunded paddy fields and 25 to 30 per cent in the dugout ponds in the low lying area. Studies carried out to examine the progressive changes resulting from reclamation reduces the run-off, enhances the ground-water recharge in the area and minimises the drainage needs.

Reclamation of Saline Soils

Drainage measure: The provision of proper drainage is of paramount importance in the case of saline soils. For the coastal saline soils as obtaining in Sunderbans area of West Bengal, provision of suitable drain to remove excessive rain water and to store the later part of the rainfall for use as irrigation source of water has been found to be of great advantage. The experiments conducted under a coordinated project for research on water management and soil salinity have shown that in a watertable saline area of sandy loam soil at IARI, New Delhi, provision of 1 m deep open ditches 32 m apart resulted in high grain yield of crops like sorghum, maize and wheat as against complete failure or very poor yield in the undrained area.

Mulching for improvement of soil physical properties: The studies by scientists showed that mixing of rice husk at 10 t/ha with surface soil by ploughing during the fallow winter period after the harvest of kharif rice significantly increased the rice yield during followed kharif season. Further, there was reduction in evaporation of soil moisture leading to decrease in salinity. This practice can be utilised as an alternative where it is not possible to grow rabi rice crop due to lack of irrigation water.

Selection of crops and varieties: At the CSSRI, Regional Research Station, Canning, large-scale screening of a large number of rice germplasm collected locally from different saline areas of India and abroad, led to the identification of four genotypes which are very much salt-tolerant and could be used as parent in recombination breeding programme. Attempts have been made to evolve the varieties by hybridization and mutation breeding. A new mutant strain of rice, named 'CSSR-4' has been evolved at the Regional Research Station, Canning, by subjecting the seeds of variety 'IR-8' to X-irradiation. The new strain matures about 2-3 weeks earlier and also yields more than 'IR-8'. From the screening of a large number of germplasm of barley carried out so far, the variety 'DL-120' appeared to be a better tolerant genotype than varieties 'Ratna' and 'RS-6'. In high salinity (ECe 6.35-19.28 mmhos/cm) variety 'DL-41', 'RD-137' and 'RD-167' with yield potential and 2.0 t/ha appeared to be better suited. Similarly some preliminary trials have been conducted to find out critical salinity levels up to which sunflower could be grown. In case of sugarbeet crop, it was found that variety '*Maribo resistapoly*' grown in upland, less saline soil gave 294.2 q/ha yield. However, there was decrease in sugar content with soil salinity.

Physiological basis of salt tolerance. A comparative evaluation of salt tolerance under coastal saline soil conditions has revealed translocation of Na from root to other parts in case of cultivated rice and accumulation of Na in root itself in case of more tolerant wild rice. Based on the germination pattern under different salinity levels at Canning the rice varieties have been divided into a few distinct groups.

Although the saline soils constitute about 50 per cent of the salt-affected lands in the country, scientific information regarding characterisation, reclamation, crop cultivation, etc. is still meagre. Intensive research to know in detail the nature and problems of the saline soils and also to work out suitable reclamation methods is, therefore, needed.

During the Seventh Five-Year Plan, it is proposed to strengthen the already existing research facilities at CSSRI, Karnal, besides establishing new Regional Research Stations to work in saline soils in greater depth. Besides, strengthening the All India Co-ordinated Projects on Use of Saline Water in Agriculture and Integrated Water Management and Soil Salinity, in progress, a new coordinated project for Research on Management of Salt-Affected Soils will be carried out at few selected locations in the country. Looking at the success of the technology of alkali soil reclamation, many states have established corporations for reclaiming these lands and already sizeable areas lying barren have been brought under cultivation with this technology.

It is hoped that major proportions of the hitherto cultivated salt-affected land will be brought under reclamation and substantial quality of foodgrains will be additionally produced annually from lands where not even a blade of grass could be grown earlier.

India is one of the major centres of the origin of several important crop and animal species, thus making it a large natural germplasm bank. The diversity in plant and animal kingdom is further accentuated by varied soil and agroclimatic conditions in the natural habitat for use in the crop improvement programmes. A Bureau of Plant Genetic Resources, set up in 1976, organises exploration and collection of germplasm, documentation and quarantine individually and in collaboration with International Plant Genetic Resources Institute. Similar bureaus of fish and genetic resources are being set up to preserve indigenous breeds or strains of large variety of animal species.

Post Harvesting Technology

In the area of farm machinery and implements, several useful machines and implements have been produced, including bullock-drawn sweeps; chisel-plough, puddler, manual and animal drawn seed-cum-fertilizer drill, power tiller operated paddy harvester, tractor oriented reaper-binder, and multi-crop thresher. Besides, several tools have been further improved like hand hoes, ploughs, harrows, and cultivators. In the case of processing equipment several innovations have taken place. Mention can be made of equipments like grain dryers for cereal crops, groundnut decorticator, sunflower and groundnut cracker. Several designs of cowdung and biogas plant have been developed and simple technologies have been worked out to recycle agricultural wastes.

Major new thrusts have been given to agricultural research in the country which includes areas such as conservation and strengthening of ecological infrastructure, raising the yield potential of crops, enhancing stability of production, improving post-harvest technology, energy management in agriculture, and strengthening of transfer of technology. A major programme is going on in the field of biotechnology as applied to agriculture to undertake basic work in areas of molecular biology, genetic engineering, biological nitrogen fixation, photosynthesis, tissue culture and enzyme engineering.

If the above technologies are transferred to the field, they can, on the one hand, acquire the strength of the super farm methodology and at the same time avoid the difficulties in terms of social, ecological and energy costs inherent in the super farm procedures. Making small farmers acquire the strength of super farm cultivations, while avoiding their weaknesses, is thus a major challenge to agricultural technologists and planners working in India. If this task of transfer of technology is successfully accomplished, it will be possible to raise the average productivity of all farming systems and thereby help the country to derive benefit from its vast untapped production reservoir. If our three major resources—sunlight, water and the human population—could be linked in a symbiotic manner through green plants, the country could bid farewell to not only the import pathway of meeting needs of basic agricultural products but also to supply excessive production to other developing countries.

Exploration, Mining and Processing

INDIA HAS made significant achievements in the field of mining technology, the backbone of industrial, civil and military activities and enjoys tremendous export potential today. It has now the expertise to produce most of the machines and apparatus required for pre-mining activities. All types of survey equipment are indigenously manufactured including drawing office equipment, electronic calculators and microcomputers. In the field of exploration, rotary drilling equipment, calyx rotary drills and their accessories have been developed.

Mineral Exploration

The history of mining in India is very old. It is well known that during the Mohenjodaro and Harappan civilisation, various minerals were being used in India. The *Arthasashtra*, which was written around 300 BC, is one of the best records of the mining activity left by our ancestors. According to Pliny in the first century A.D. India was a leading producer of gem stones and gold. That some of the world's most famous diamonds were produced by this country has gone on record in the travellogue of Tavernier. India's quest for knowledge of the unknown facts of the earth's interior is one of the oldest in the world. Modern geological appraisal commenced in India in the early 1950s of the last century with the exploration for coal in Raniganj Coalfield. The Geological Survey of India, the third oldest organisation of its kind in the world, was set up in 1851. Oil exploration commenced in Assam in 1866. The discovery of vast reserves of iron ore in 1902 and manganese ore in 1904 fetched for India a place in the industrial world with the setting up of the first steel plant in the country and in surpassing the then record of world production in manganese. Diamond drilling for copper was commenced in 1906 in the Singbhum belt, Bihar, which ultimately resulted in ore and metal production of copper. With more than 130 years of experience and ability, Indian geological expertise which is the forerunner of exploration is forging ahead with renewed vigour every year.

Minerals exploration is an effort to find out and arrive at a maximum number of new economic mineral deposits or ore-bodies within a minimum cost and in a minimum amount of time. Minerals exploration and development can be fundamentally divided into three stages namely, search for and recognition of prospects—a preliminary appraisal stage, detailed exploration and development in selected prospects for conversion of specific prospects into working mines, and commercial exploitation of deposits.

'Mineral resources' is a general term which gives a rough idea of the availability of minerals without explicitly taking the economic feasibility of obtaining the minerals/metals. Resource is a new source of supply. The conception of 'ore reserves' refers to specific quantification of various parameters including the grade width, shape of ore bodies and other geological considerations. Different categories of reserves based on degrees of reliabilities are in vogue in the world.

Figures for ore reserves which can be put in any practical use are estimates and are inevitably subjected to some margin of accuracy. Only when a deposit is fully worked out can one be sure of the reserves contained in it. Thus 'reserve estimation' while excluding hair-splitting precision emphasises rational geological judgement.

India produced 22 minerals valued at Rs. 649 million during 1947. By the end of the sixties, the value shot up to Rs. 5,420 million of 52 different types of minerals. At the end of the seventies the value of annual minerals production stood at Rs. 22,557 million. The dawn of independence ushered in an era of industrialisation and mineral exploration was given pride of place in developmental activities of the state, as mineral raw materials constitute the backbone of industrial production.

Sustained efforts for the discoveries of new and virgin minerals deposits have resulted in major additions to the mineral inventory, notably in bauxite, coal, copper, gypsum, iron ore, limestone, petroleum, tin and tungsten. Coal reserves/resources have improved fourfold since independence by 1973 and today the addition is five times that of what we had in 1947. Resources of petroleum and natural gas, in which India was considered to be chronically deficient have put us on the verge of self-reliance in these products. Fertilizer minerals, which are essential for agricultural production have registered spectacular increase. There has been a sea change in bauxite from 25 million tonnes in 1947 to 250 million tonnes in 1973, now standing at more than 2,500 million tonnes. In the nonferrous sector, copper, lead, zinc ores have shown remarkable increases from a meagre two million tonnes to more than half a billion tonnes today. Similar significant increases are noted in minerals like barytes, chromite, manganese, gold, asbestos etc. In the field of strategic minerals like tin and tungsten which were thought to be non-existent for commercial exploitation significant discoveries were made recently. These were possible due to organised exploration efforts mostly those of state agencies.

In the early seventies, the government decided on an exclusive state organisation for speeding up exploration activity, as a result of which the Mineral Exploration Corporation Limited was set up in 1972 as an autonomous public sector enterprise in the decade of its existence with an impressive record of exploration inputs resulting in additions of reliable reserves for major investment decisions. It was the MECL's effort which resulted in the recent major investment decisions taken on the mines and plants such as the Malanjkhand Copper, Madhya Pradesh, Panchaatmali Bauxite, Orissa, a large number of coal blocks of CIL, Mailaram Copper in Andhra Pradesh, Ambamara lead-zinc deposit, Gujarat etc. A lot still needs to be done in the field of mineral exploration and exploitation.

The life of the existing resources base will be critical in copper, lead-zinc, manganese and chromite in about a decade. There is an urgent need to augment the resources base by sustained, well-directed efforts for further exploration which will enable the achievement of the planned average annual growth rate of 7 per cent.

India is endowed with rich natural resources, particularly in selected minerals like iron ore, bauxite, chromite, manganese and coal. It has been envisaged that by 2000 AD the existing annual exploration inputs for mineral development would be doubled to an annual rate of about 12 lakh metres of exploratory drilling and 25,000 metres of exploratory mining. To achieve this gigantic effort, an expenditure of Rs. 4,400 million is envisaged for the seventh plan period (1985-90).

The exploration effort planned by MECL in the terminal year 1989-90 (of the seventh plan) as over 300,000 metres of exploratory drilling and 20,000 metres of exploratory mining and matching geological inputs, which constitutes about 95 per cent of the total exploratory mining work in the country and about half of the drilling effort. The projected annual inputs of MECL by 2000 AD are about 500,000 metres of drilling and 25,000 metres of mining.

A critical study of the pattern of exploratory drilling inputs planned for the seventh plan (1985-90) indicates that the prime source of energy in India i.e. coal continues to enjoy the pride of place. In fact the share of coal exploration has been on the increase since 1960s. During the seventh plan it was envisaged that to meet a demand of 250 million tonnes in 1990 drilling for coal would be of the order of 2.2 million metres which is about two-thirds of the total plan effort. The major effort is unique in the international exploration scene. Further by 2000 AD to cope with a likely coal demand of 400 million tonnes per annum, the terminal decade of the 20th century would have to plan a gigantic effort of about 5 million metres of exploratory drilling. Coal exploration in India thus becomes the lifeline of energy and the industry. The scale of inputs in work content for 2000 AD and the expenditure planned for seventh plan (1985-90) assure a fair degree of success in ushering in an era of self-reliance by the end of the century.

There is not only a need but an urgent necessity for intensive exploration efforts in the country. Minerals development is of crucial significance in bringing about rapid increases in the GNP of the country. The only way of increasing this is by accelerating the pace of development in the fields of agriculture, transport, power and heavy industries. All these are large consumers of mineral raw materials. Capital mobilisation is essential for prosperity and hence investments capable of yielding fast and large returns receive encouragement. Well conceived and directed programmes of mineral exploration, under favourable conditions, meet these requirements. Mineral commodities are important in international commerce as foreign exchange earners/savers. Minerals development often acts as a catalyst of general economic development. Mineral exploration in developing countries like India serves not only the national but also the international interests as no country is self-sufficient in all minerals. Rapid depletion of mineral resources in advanced countries has taken place due to intensive exploitation leading to dense industrialisation. From the long range point of view, the requirement of mineral raw material for industries in these countries will have to be met increasingly from new discoveries in countries like India.

Mineral deposits are rare, being concentrated forms of wealth. They are wasting assets. These factors influence all activities for mineral exploration. The broad strategy of mineral exploration consists of narrowing down the field of operation by a succession of stages in the exploration programme leading to detailed operations in selected prospects, thereby converting them into working mines. While available opportunities should not be missed. Unwarranted risks should not be taken. Search for minerals in the past was often of the nature of a private treasure hunt. The position has radically changed now. Today the objective is directed towards developing potential mineral wealth to the maximum extent possible to provide the ever growing raw material base for industrialisation which will in turn make significant contribution to the national economy through foreign exchange earning/savings. In relation to the large object, scientific, systematic, integrated programmes of exploration are of far greater significance than a random search for burried treasure which was in vogue in the past.

Exploration programmes for concealed mineral deposits are based on scientific anticipation of the available exploration opportunities. The factors which limit these opportunities in a given mineral-belt should be recognised. Exploration opportunities are not static. With progress in exploration, new prospects will come to light. Technological advances may bring what was formerly a marginal or sub-marginal grade within the minerable grade. It is, therefore, necessary for an exploration strategy to not only consider the grade of ore at present but also the industrial and sub-marginal grade which could be of possible use in the future. With various innovations that are taking place in the mineral industry, there is an obvious necessity to fall back on low grade ores as was witnessed in copper ores.

Programmes of exploration have to be properly integrated to obtain maximum results in minimum time at a minimum cost. The integration has to take account of specific exploration needs of the region under consideration, the available exploration opportunities and the scope and, limitations of different methods at different stages of exploration.

An important aspect of the strategy of mineral exploration in India is the question of exploration and exploitation of small mineral deposits. We are about to reach a stage when the known large-sized deposits, under active exploration or exploitation, will be exhausted. In course of time, we would be compelled to explore the medium to small deposits. The advantages in developing small deposits are: gestation period can be small, exploration can merge with development, investments involved are much smaller and production can commence within a short time.

Ore hunting is not an easy task. There is scarcely an engineering problem with so few rules to guide and with so many alternatives to choose from. The easily accessible deposits are becoming scarce and the cost of locating a prospect is increasing. All mineral deposits are geological features and results from the operations of geological processes in time. In a fundamental sense, all mineral deposits are geological anomalies.

The ultimate objective of mineral exploration is the exploitation of the mineral wealth. This objective cannot be realised at one stroke. Mineral deposits are rare and for the purpose of exploitation very detailed information, obtainable during exploration involving considerable expenditure of time and money is necessary. Such intensive operations will be justified in only promising prospects. Final appraisal of mineral deposits will have to be related to the exploitation of deposits. A long and difficult path has to be trailed before a mineral prospect is converted into a working mine.

Mineral exploration in the past has been for the most part a random, uncoordinated effort by individuals with little or no scientific background. Exploration was thus based on surface indications of mineralisation, ancient workings, slag heaps, etc., and limited use of drilling and exploratory mining. But now revolutionary changes have taken place in the purpose, scope, tempo and nature of mineral exploration in India. Today, programmes of exploration are adequately integrated to ensure availability to diverse data base within a short time. The work commences with preparation of geological maps and regional investigations of mineral district. In addition to conventional geological methods, photogeological, geochemical, geophysical, remote sensing, isotope, geology, thermal mapping, etc., are being adopted. Satellite maps are being used for location of major areas of mineralisation and other geological parameters. In the field of detailed mineral exploration various agencies like MECL, CEMPDIL, SCCL, NCL and other state agencies are in the field. The MECL is the single largest exploration agency in the country which was specifically created by the government of India with the sole purpose of carrying out detailed exploration of all minerals, except oil and gas and radioactive minerals. It may be pointed out that techniques do not create, but assist in the discovery of economic mineral deposits. Selection of techniques is most important and should be related to an objective and to working hypothesis.

The basic approach of India's Mineral Exploration Corporation has been not to limit the objective of operations to the narrow purpose of finding ores in individual prospects but to regard the entire exploration and providing operations as a major programme of scientific investigations. The result is that a constantly growing treasure of scientific knowledge of great practical significance to mineral districts of the country is being created. Full advantage is being taken from this cumulative knowledge during execution of mineral exploration programmes.

The Hindustan Zinc Ltd. is working towards increasing the levels of self-sufficiency in the country's zinc and lead requirements. It is expected to achieve its target by the year 1987, the Hindustan Copper Ltd (HCL) has lent a dynamic dimension to copper production in the country. The company has to its credit some major contributions towards technological improvements in mining, benefication, smelting hydro-metallurgy and by-product recovery. Trackless mining has helped in rapid development of mines enabling higher levels of production, it has also developed a sub-level method to stop using large dia (162 mm) blast holes over level intervals of 60 mm. The need for intermediate sub-levels for drilling has been eliminated in this method.

The Bharat Gold Mines Ltd. has developed technology for 100 per cent recovery of gold from rocks. Its achievements in rock machines research have won international recognition. The major focus for research is on suppression of dust pollution and effective method for mineral recovery.

In surface mining, India has taken giant strides with upgraded technology and giant equipment. The Kudremukh iron ore mine has many firsts to its credits such as use of 10.8 m^3 shovels, 120 tonnes diesel electric trucks, 312 mm electric drills, site-mixed slurry explosive systems, long distance transport of concentrates and computer control. India's largest base metal surface at Malanjkhand uses 10 m^3 shovels, 9.2 m^3 front end loaders, 85 tonne and 50 tonne dumpers and special purpose drills. The planning for pit slopes there required a major geotechnical exercise using core orientation techniques for diamond drilling and installation of pneumatic piezometers.

The Geological Survey of India (GSI) has made systematic mapping and exploration of mineral resources rendering valuable service in laying a firm foundation for the development of the country's mineral resources. It makes extensive use of geochemical and geophysical techniques in exploration. To enable the coverage of large areas, airborne geophysical surveys are undertaken. Satellite derived data from the American Landsat Programme resulted in the preparation of alignment map of the country. It is now preparing for fully utilising the proposed Indian Remote Sensing Satellites. Computerised data processing facilities are being established for efficient collection and classification of input data. Taking up prospects identified by GSI and conducting detailed exploration and project studies the Mineral Exploration Corporation Ltd. (MECL) has made significant achievements, since its creation in 1972, like exploratory activity leading to the first open cast copper mine at Malanjkhand and the establishment of the National Aluminium Company for mining the bauxite discovered on the east coast. It has done 1.21 million metre (m) of drilling 56,000 m of mining and has thereby helped to establish additional reserves of 15,734 million tonnes of coal, iron-ore, bauxite and other minerals.

Mining Equipment

Intensified underground mining activity in India called for the need to manufacture all types of underground machines and today almost all the machinery needed to win minerals from underground mines are manufactured by state-owned organisations and units and also by private companies. These include scrapers and slushers, rock shovels, cavo and emico type LHD, pneumatic and electric drills, electro-hydraulic face drills, roof bolting jumbos, belt conveyors, battery/diesel/trolly wire locomotive and rope haulages and hydraulic support. The use of electronics and computers in mine planning and operations is gaining ground.

The earth-moving equipment industry in the country has played a very vital role in the growth of mineral exploitation. The nation is now self-sufficient in respect of the machinery required for opencast mines. The degree of mechanisation varies from mine to mine. To suit the wide spectrum of the activities, opencast machinery is also manufactured in wide ranges. Amongst the important items manufactured in India are tractors, dozers, scrapers, wagon drills, self-propelled DTH rotary, blast hole drill, steel tools and accessories. Crawlers and wheel mounted rollers, rippers and dumpers of various types and capacity are on the list of machineries manufactured in the country. Likewise transport equipment manufactured includes dumpers and tippers, haulage trucks locomotive and wagon shunters, aerial ropeways, mine ropes, headgers, skips cages and pumps of various types and capacities are also indigenously designed and manufactured.

Safety apparatus and appliances manufactured in India include, amongst others, respirators, fire extinguishers and other fire fighting equipment, cap lamps, safety lamps, safety torch, smoke helmet, gas detectors, resusication apparatus, velometers, kaka thermometers, safety goggles, helmets and safety boots.

This is happening largely through technical assistance provided to industry by the Geological Survey of India, Mineral Exploration Ltd., Indian Bureau of Mines and the Central Mining Research Station of the Council of Scientific and Industrial Research. Besides the Bharat Gold Mines Ltd., the Hindustan Zinc Ltd., Hindustan Copper Ltd., and the Bharat Aluminium Ltd. are conducting research and development work which has given a major impetus for setting up an engineering industry to cater to the rising needs of the mining industry. Many engineering industries in the country are engaged in the production of equipment through transfer of know-how and technology by noted international firms and based on indigenous designs.

Till the 1950s, the Indian coal mines were mainly worked by manual pick mining, and the use of explosives was very limited. India first started manufacturing high explosives in 1958 in collaboration with Imperial Chemical Industries (P) Ltd. of UK, and floating a new company, Indian Explosives Ltd. (IEL). The second company IDI Chemicals Ltd. came into existence in 1961. Before it, the country depended entirely on import. In the wake of intensive mechanisation, India has developed techniques to manufacture high explosives in wide ranges to suit the prevailing conditions. The blasting agents manufactured in the country include the permitted explosives for use in the underground (UG) coal mines and non-permitted explosive for use in opencast and non-coal underground mines.

In the permitted category, the explosives manufactured are gelatinous equivalent sheaths, semi-gelatinous and powdery type. In non-permitted category, special gelatine, opencast gelignite belex GI and hectorite and nitroglycerine based explosives and GNI slurry explosives. Amongst non-permitted explosives, aluminised slurry explosives, e.g., Energel, Superel and Agunal are the recently developed explosives. From the days of total dependence, India has come a long way in achieving self-sufficiency in explosives. The research centres for the explosives manufacturing organisations are constantly engaged in developing new products, techniques and systems as well as adopting the latest technological developments taking place on a global basis.

Through regular investigation study and application of advanced knowledge breakthrough have been made in the field of strata control and methods of mining support. Some of these techniques have been utilised for better planning of new mines. In the field of subsidence control, the different parameters of surface movements due to underground mining have been determined to anticipate subsidence slop strains and angle to draw and to study the feasibility of extraction underneath different surface structures. In the field of strata control, equivalent material modelling technique has been perfected to evaluate the response implication on safety, and this helped evolve suitable techniques for working under river beds, acquifers and built-up structures as well as for mining of thick, flat or inclined seams.

The laboratories have made many achievements in the field of support and roof control. Different types of roof bolts and methods of roof bolts and methods of roof stitching using scrap haulage ropes have been designed and developed as fast, economical and effective methods of roof support in different circumstances. The blasting efficiency of various types of explosives under different conditions have been assessed and it was possible to develop a few explosive compositions. The other achievements are in the field of gasifications, spontaneous combustion, detection of dangerous concentrations of gases, rescue apparatus, ventilation, safety equipment, and last but not the least in the field of environmental protection in mining areas.

In the field of coal utilisation, a mechanised process for conversion of low grade coking coals into domestic coke with recovery of tar and minimised air pollution has been successfully developed. Indigenous technologies have also been developed for production of diverse types of domestic fuels in shaped/noduled form using mainly slack coal as feedstock.

A commercial scale low temperature carbonisation plant with internal heating system has already been commissioned and another plant with external heating system to produce both domestic coke and medium calorie gas is under construction near Calcutta. A beginning has also been made in the production of chemicals from coal by adopting the coal gasification route in two fertiliser plants at Talcher and Ramagundam. Studies are being conducted in partial briquetting, preheating of coal charge, stamp charging and coal dust injector to reduce the consumption of the scarce coking coal. The benefication plants proposed for coking coals and power coals are expected to generate an enormous quantity of rejects with an ash content of 60 to 70 per cent. Generation of power from these rejects using fluidised bed combustion system is under trial.

Improved techniques of coal preparation such as introduction of three product cyclones, improved jugs and new fine coal benefication systems are being adopted. The oil agglomeration process for benefication of fine coal is under semi-commercial trial.

A number of electronic system equipment like central despatches system for underground (UG) mines, sound powdered telephones, cage communication system amplifier telephone, vehicular communication of UG mines, VHF communication system for location of trapped miners and telemonitoring devices have been developed in the country in the area of communication, safety and industrial electronics. This would facilitate optimum utilisation of mine machineries. Besides, some of the notable developments in the various fields of mining electronics systems have been temperature monitoring microprocessor based mine winder, online coal ash monitoring, methane monitoring and various communication system, defectograph and EM prospecting equipment.

Aluminium

In the field of aluminium metallurgy, India has now the expertise to absorb the technological revolution taking place in the area of aluminium metallurgy, the third most abundant element on the earth's surface after oxygen and silicon.

Technological changes in the production of aluminium in the country have largely originated in the general advances in science and technology although there is still no established equipment industry catering specifically to meet the needs of the aluminium industry. The same conventional Bayer alumina process and the Hall-Heroult electrolytic technique for reduction of alumina continues to be the technology in use for all aluminium units in the country including NALCO.

In the Bayer alumina process, improvements have been effected mainly through the introduction of continuously operating equipment, development of equipment suited to the specific demands of the alumina plants, incorporation of the higher capacity equipment and the adoption of the latest development from other fields like the use of modern pressure filters continuous vacuum filters, fluidized bed calcination and automation. The use of computers has been particularly helpful as a large number of variables are involved.

The production of aluminium from bauxite is two-step process : refining bauxite to obtain alumina and smelting alumina to produce aluminium. Bauxite contains a number of impurities, including iron oxide, silica, titania, and water. Bayer's process, with some modification, still the most widely used and commercially successful method in the country for the production of alumina, and virtually all aluminium is smelted from alumina using the Hall-Heroult electrolytic process. The Bayer process involves four steps: digestion, calcination, precipitation and calcination.

In the first step, bauxite is ground mixed with a solution of caustic soda and pumped into large pressure tanks called digesters, where the ore is dissolved under steam heat and pressure. The sodium hydro-oxide reacts with hydrated aluminium oxide of bauxite to form a saturated solution of sodium aluminate; insoluble impurities, called red mud because of their iron oxide content settle at the bottom. During clarification the mixture is passed through a series of pressure-reducing tank (called blow-off tanks) and filter presses. Cloth filters catch the red mud, which, except at plants where lower grade ores are refined, is discarded. A resultant green liquor passes through filters into cooling towers (heat exchangers) and then into tall, silo-like precipitators. Sizeable amounts of hydrated alumina crystals are added to the solution in the precipitators as "seeding" to hasten crystal separation.

The seed crystals attract other crystals and form groups physically heavy enough to settle out of solution. This precipitate of aluminium hydrate crystals is filtered out, washed to remove impurities, and heated in long, rotary kilns at temperatures in excess of 980° C. Free water that is chemically combined with the aluminium hydrate are driven off, leaving commercially pure alumina—or aluminium oxide—a superdry, fine white powder similar to sugar in appearance and consistency. It is still half aluminium and half oxygen by weight, bonded so firmly that neither chemicals nor heat alone can separate them.

Alumina produced by the Bayer process is quite pure, containing only a few hundredths of one per cent of iron and silicon and traces of residual soda. In addition of being the primary raw material for producing metallic aluminium alumina is an important chemical in its own right. It is used widely in the chemical refractories, ceramic and petroleum industries.

Refining four tonnes of bauxite yields about two tonnes of alumina. A typical alumina plant, using the Bayer process can produce almost 3,000 tonnes of alumina per day.

In the smelters, improvement in the efficiency has come mainly from the development of the large cell size, use of prebaked anode, new additives, developments in busher system, dry scrubbing and the automation. Microprocessor based control provides significantly improved process control and optimization, in a modern smelter based on the Hall-Heroult smelting process, aluminas dissolved sheets lined with carbon—that are filled with a molten electrolyte or conductor, consisting most of an aluminium compound called cryolite. By means of carbon electrodes, direct current is passed through the electrolyte to the bottom of the cell, causing a crust to form over the surface of the molten bath. Alumina is added on top of this crust where it is preheated by the heat from the cell (about 950°C) and absorbed moisture is driven off. Periodically, the crust is broken, and the alumina is stirred into the bath to maintain proper concentration. The process is continuous. Additional alumina is added to the bath to replace that consumed by reduction. Heat generated by the electric current maintains the bath in a molten condition so the fresh alumina is dissolved. Periodically molten aluminium is siphoned off.

There are three major groups of research and development (R&D) institutions in India which have been active on selected research problems related to the aluminium industry. They are: in-house R&D centre of the aluminium producing companies and research laboratories of the CSIR. In addition to these some universities like Banaras Hindu University, Varanasi, Indian Institute of Technology, Delhi, Indian Institute of Science, Bangalore, have also taken up occasional studies related to aluminium.

INDAL is the most conscious of the value of research and development with a tradition of about three decades of active research relating to applied aspects, product and process innovation and development, substitution of imported materials, recovery of values from plant wastes, energy conservation, effluents disposal and ecology improvement.

HINDALCO's R&D activities do not cover as wide areas as INDAL's portfolio of research and development programmes. The company's main emphasis in R&D has been on recovery of byproducts from plant wastes and waste utilization. Work on reduction in caustic soda consumption, quality control of pitch for improving on net carbon consumption by extra testing, use of modern pitch and pitch aeration plant, development of chemical additives for dewatering of aluminium hydrate prior to feeding the same in rotary kilns for fuel economy are among the achievements made by the company. The principal concern of BALCO's R&D centre has been the problems up to the alumina production stage. Besides, fully equipped bench scale testing facilities for bauxite, it has a pilot plant for evaluating the bauxite samples for production of alumina.

Over half a dozen Counil of Scientific and Industrial Research (CSIR) laboratories have worked on problems mostly concerned with aluminium applications and project development, though some projects have dealt with production technology. The work at National Metallurgical Laboratory, Jamshedpur, Central Electro-Chemical Research Institute, Karaikudi, Regional Research Laboratory (RRL), Bhubaneshwar, and RRL, Bhopal, deserves special mention.

The early work at NML was concerned with the evaluation of the Indian bauxite for the production of alumina, and though considerable expansion of activities was planned at one stage in mineral benefication and electro-cum-hydro metallurgical operations with the assistance from the Department of Mines. The later activities at the laboratory related to the development of special aluminium alloys for electrical industry and constructional applications; production of synthetic cryo (aluminising) of steel and aluminium alloys for anodic production. The Seventh Five-Year Plan proposals of NML contain a number of projects under aluminium alloy technology, and one dealing with the development of alternative routes for aluminium, viz., to establish the parameters of carbothermic reduction process for aluminium production.

Research at the Central Electro-Chemical Research Institute (CECRI) has concentrated broadly on the production of synthetic cryolite from the waste flue gases of super phosphate industry; development of corrosion protection coatings such as chemical conversion coating anodising platings, etc., use of aluminium as anodes in batteries, production of aluminium litho plates and aluminium capacitators, development of special alloys for electrical industry and of a solder and flux for joining aluminium conductors. The Seventh Five-Year Plan proposals of the laboratory include development of aluminium chloride electrolysis through solar cells for aluminium production and development of lithium aluminium alloys by fused halt electrolysis.

Studies have been carried out to obtain aluminium from aluminium trichloride by fused electrolysis at the RRL, Bhubaneshwar. A technique has also been developed at the laboratory to recover vanadium from the alumina industry as iron vanadate. It has also developed carrier grade aluminium by homogenisation and precipitation techniques. The Seventh Plan Programme of the laboratory include further work on the precipitation of aluminium by fused salt electrolysis of aluminium chloride, characterisation of red mud and large scale studies to recover metallic values from it, and development of special alloy.

RRL, Bhopal, a new laboratory of the CSIR, has plan to become a major centre of excellence in view of the large bauxite deposits in Madhya Pradesh. The areas identified for special studies are reduction in the energy consumption in aluminium production, use of aluminium in transportation systems to conserve petroleum based energy; developing inexpensive aluminium equipment for tapping solar energy; using solar and biomass energy to process aluminium alloys; to develop inexpensive ways of producing aluminium-silicon alloys directly from bauxite.

Despite all these achievements, the Indian aluminium industry has suffered from serious shortages of power, which is a critical input, resulting in serious under utilisation of the available capacity and frequent crisis. The industry has very special environmental problems encountered in the disposal of red mud and control of fluoride emissions.

India is a special case in the third world having abundant bauxite reserves, large potential of power, long experience of production of aluminium through import of technology from several leading producers of the world, and potentially a large internal market. Besides the tremendous role aluminium has to play in strengthening India's economy particularly in power transmission, transportation and building sectors, and besides its indispensability in defence and space sectors, the emergence of India as an "Aluminium Power" will have an important role in effecting a more equitable restructuring of the world aluminium industry.

Coal Mining and Utilisation

In this field, India has now mastered the techniques of efficient exploitation of its coal resources, enabling the country to move forward with a better export potential of the black diamond. Now the country has the expertise in the field of proving of coal resources, their rational and efficient exploitation, benefication and utilisation.

While the Central Fuel Research Institute (CFRI) at Dhanbad has done pioneering work in the field of coal utilisation, recovery of byproducts from coal, assessment of coal resources, combustion studies, benefication of coal, formed coke technology, solvent extraction of coal and production of cheap smokeless domestic fuel from coal, the Central Mining Research Station (CMRS) has conducted the research on topics having direct bearing on safety in mines and mining of coal. Studies, undertaken by CMRS have brought in knowledge in the fields of strata control surface subsidence, roof supports, design of pillars and barriers, methane drainage, mine ventilation and stowing.

In the field of slurry transportation of coal, the Regional Research Laboratory in Bhubaneshwar has developed know-how for slurry transportation of coal and other materials. The technology has been found to be at least 40 per cent cheaper compared to rail or road transportation. The laboratory is now engaged in providing the technology for setting up of 50 km long slurry pipeline for the transportation of 0.5 million tonne of coal from New Majari to Chandrapur power station in Maharashtra.

The laboratory has also set up a pilot plant where facilities are available for determination of practical characteristics like density, size distribution, ash and moisture content, terminal and prevented setting velocities, etc., used for the analysis of slurry behaviour. The plant is helping the laboratory's scientists in providing the necessary technology and engineering data for the design of commercial slurry pipeline systems.

In the field of conversion of coal to oil, the Central Fuel Research Institute (CFRI) has developed direct hydrogenation process. Synthetic crude oil has been produced at a pilot plant set up by the institute using washed Raniganj coal with 10 per cent ash. The crude evaluated at the Indian Institute of Petroleum in Dehradun was found to satisfy ISI specifications.

Coal, under the pilot plant, is first demineralised to about 10 per cent mineral matter, pulverised to minus 200 mesh, mixed with the catalyst and vehicle oil (derived from the process itself) to form a paste. This paste is pumped into the reactors along with the hydrogen at a high temperature of 480°C and a pressure of 250 kg/cm through a preheater. The products of reaction are separated and collected in stages. The worked up products which can be considered as 'syncrude' constitute three fractions, viz., light oil, middle oil and the heavy oil which is sent back to process to serve as a recycled vehicle oil. The middle oil fraction is refined to specification grade.

A major thrust for conservation of coal is being provided by taking up schemes for scientific investigations and actual field trials under the Science and Technology Plan of the Department of Coal. New methods of mining, namely, hydraulic mining for steep and soft coal wide-stall system of mining for extraction under built up areas, extraction of coal standing on pillars in thick seems by blasting gallery method are under various stages of implementation. These have a direct bearing on increasing the percentage of coal that can be extracted.

In the field of coal benefication various institutes have made significant contributions in development of computer programme for simulation of coal benefication process and utilisation of washery rejects. The Central Mine Planning & Design Institute Ltd. (CEMPDIL), in association with the Bharat Heavy Electricals Ltd., has been actively engaged in developing fluidised bed technology particularly for utilisation of washery rejects/tailings. The results of pilot plant trials have been found to be quite encouraging.

CEMPDIL has installed a 5-tonne per hour Batac Jig Pilot Plant at Patherdih washery to study the performance of this machine for ashing various types of coals. The results obtained from the newly installed jig pilot plant and that from the existing cyclone pilot plant can be utilised to study techno-economics of the two washing systems for planning future washeries. The Regional Research Laboratory, Bhubaneshwar, has developed a flotation column which holds good promise for upgradation of fine coal particularly ultrafines. With a view to generate data to assess the comparative techno-economic advantage of using flotation columns vis-a-vis conventional froth flotation cells for the recovery of fine coal, particularly ultrafines. A scaled up model of the flotation column will soon be installed at Sudamdih Washery.

The approach to research and development activities in the field of coal utilisation is guided by the quality and quantity aspects of the extractable indigenous coal resources vis-a-vis the demand for such coals. Since the steel industry and the thermal power sector account for more than 60 per cent of the country's coal consumption, greater attention is being paid to R&D activities in utilisation of coal in these sectors.

Another major problem facing the country has been to meet the fuel needs of the common man, especially in view of increase in price of oil products and environmental and ecological damages associated with increased deforestation. Therefore, R&D activities in this field are also receiving a high priority. A new field for use of coal as raw material in the manufacture of carbo chemical where coal is likely to provide suitable substitute for petroleum products.

The main objects of R&D activities in the field of coal utilisation in the steel sector is the conservation of scarce cooking coal resources. This is sought to be achieved by identification of new sources of cooking coal, maximising the use of substandard coking coals and non-coking coals in iron making processes and evolving new processes of iron making wholly based on non-coking coal.

In order to reduce the consumption of hard coke in the blast furnaces several new techniques like coal dust injection, stamp charging of coal, partial brequetting of coal charge, and formed coke technology were introduced. In the coal dust injection technique which involve injection of low ash non-coking coal is introduced into the blast furnaces through the tyres reducing the consumption of coke. An experimental coal dust injection programme is now being carried out in Blast Furnace No. 2 of

Bhillai Steel Plant. The Steel Authority of India Ltd. (SAIL) is also proposing coal dust injection at Bokaro and Rourkela steel plants.

The stamp charging of coal technology makes use of around 20 per cent of substandard coking coals in the coal blend without affecting the physical characteristics of the hard coke. Alternatively, application of this technology with standard coking coals would improve the strength of the coke. The SAIL is considering demonstration facility for this technology at Rourkela Steel Plant based on coal likely to be available from Raniganj coalfield.

The partial briquetting of coal charges technology envisages use of briquettes produced out of mainly non-coking coal in the coke oven batteries. SAIL is considering its adoption in two coke oven batteries of Bhilai Steel Plant. Adoption of this technology may result in conservation of coking coal to the extent of 15 to 20 per cent. The formed coke technology envisages production of metallurgical coke either wholly out of non-coking coal or in conjunction with coking coal. The direct reduction of iron has been suggested for adoption to eliminate the use of metallurgical coke. Two pilot plants using this technology (one of Palancha, Andhra Pradesh, under Sponge Iron India Ltd. and the other at Heavy Engineering Corporation, Ranchi, under R&D, SAIL) are in operation and two commercial scale plants in Orissa are under construction.

The aims of R&D activities in coal utilisation in the power sector are two-fold : (a) achieving improved efficiency in thermal power generation and (b) utilising very low quality coal/washery rejects for power generation. As the main producer of power plant equipment in the country, the Bharat Heavy Electricals Ltd. (BHEL) is carrying out R&D activities in these areas. The improvement in efficiency of power generation is sought to be achieved by pressurised fluidised bed gasification of coal. The coal industry is funding the development of a 150 tonnes per day pressurised, fluidised bed gasification plant at Tirchirapalli in Tamil Nadu.

The main thrust of R&D activities in domestic fuel sector is towards providing a convenient pollutionless and cheap fuel based on coal to the common man. Pilot plants for mechanised production of soft-coke, coal agglomerats non-coking coal briquettes, pellet coke and coal block are in operation.

Mining of thick coal seems by underground methods possess a major challenge in India. There are some 20,000 million tonnes of proven reserves in seams over 4 metre thick and has already been developed in pillars. Techniques of exploitation have been examined and detailed technological solutions are currently available for locations, such as East Kenduadih, Pipradih, Parasia and East Katras. Surface mining as at Mukunda Opencast have solved the problem partially. The Central Mining Research Station has formulated a proposal for the extraction of a 36 metres (m) thick, moderately inclined V-seam in the Central Chasnala block using cross-slicing method. For improving the recovery of thick coal seams with developed pillars, proposals include working the 8 m thick Kenda seam with sub-level caving, use of descending slides at Nandira Colliery and hydraulic mining at Baragoloi Colliery for extraction of 18 m seam.

To facilitate the introduction of electronics in an integrated manner in the sector, 32 such systems like communication systems, safety instrumentation and industrial systems which include use of infrared technology have been identified for introduction in the coal mines. About 100 mines are proposed to be electrified by 1989-90. In addition 4 model mines have been selected to be equipped with mine wide modern electronic packages. A total mine management system for Rajrappa opencast mine has also been undertaken. A scheme for a reliable COAL NET Communication System through 10 dedicated INSAT earth satellite stations located at different strategic points with an estimated expenditure of Rs. 100 million has been drawn. A massive programme to install computer system in the mine areas and headquarters of coal companies has been drawn to establish an effective management information system.

In a quest to find optimum method of extraction of coal in thick, sleep and deeper horizons, the National Coal Development Corporation (NCDC) has introduced deep shaft mining at Sudamadih and Moonidh in Jharia Coalfield employing horizon system of mining, a marked departure from existing practice of inseam mining. For the first time, these mines also employed mechanised shaft siking and lining. It has also helped in making significant contributions in exploration of large geological areas and introduction of modern mining techniques. The concept of large scale opencast mechanised mining materialised for the first time in the country by introduction of large capacity shovel-dumper units, draglines and large diameter blast holes drills.

NCDC and some of the leading coal mining companies successfully undertook field research and development activities in coal mining by introduction of long-wall (caving and stoving), multi-slicing long-wall for thick seam mining and knife-edge system of coal extraction for developed pillars. Necessary scientific studies were also carried out for extraction of thick steep seams by inclined and horizontal slicing. Besides these, other investigations successfully carried out were for improving the efficiency of stowing plants strata control studies for better roof control in the mines subsidence. Studies to protect surface structure, the occupational health of mines, and studies dealing with mine fires and susceptibility of coals to spontaneous heating. One of the notable contributions included extraction of coal below a railway line.

In addition to major R&D activities initiated by the industry, the government instituted a 'Science and Technology Plan' in 1975 with the Central Mine Planning and Design Institute Ltd. (CEMPDIL) as the nodal agency; for coordinating all R&D activities in coal sector being funded under this plan. The CEMPDIL apart from its primary activities of exploration, project planning and designing has been coordinating and initiating a number of schemes with a view to give practical application to laboratory findings, and to conduct field trials of various suitable mining technologies. The other agencies carrying out R&D work under this programme are the CMRS, CFRI, NGRI, educational institutes like Banaras Hindu University, Indian Institute of Technology, Kharagpur, University of Calcutta, Jadavpur, Roorkee, Osmania University. In addition to the coal producing companies themselves and the Council of Scientific and Industrial Research (CSIR) laboratories, like Central Fuel Regional Institute (CFRI), Central Mining Research Station (CMRS) Dhanbad, Regional Research Laboratory (RRL), Jorhat, RRL, Hyderabad, RRL, Bhubaneshwar; National Metallurgical Laboratory (NML), Jamshedpur, and National Geophysical Research Institute (NGRI), Hyderabad.

The methodology for selecting and implementing R&D projects and S&T plan in the coal sector has been recently revised and certain institutional improvements have been effected. A high level committee namely the Standing Scientific Research Committee (SSRC) has been set up to plan programme, budget and oversee the implementation of R&D projects in coal sector and seek application of findings. The committee has identified the goals and thrust areas of R&D activities during Seventh Plan and selected couple of major projects which will attract substantial funds from S&T grant during the plan period.

The CEMPDIL is the nodal agency for research and development activities in the coal sectors. Some of its latest achievements are as follows:

- For degasification of the isolated/small areas, the methane utilisers (bacterias) have been successfully isolated from different sources including mine water. The bacteria is found to survive even in 100 per cent methane atmosphere. Injection of these bacteria in boreholes have been successfully tried in a couple of mines and there was substantial reduction in methane percentage.
- A steel pit prop with wooden base has been successfully developed as an alternate to wooden props. This will lead to conservation of timber and forest produce.

- A mechanised system for depillaring of large reserves standing on pillars with the help of LHD and side discharge leader have been successfully evolved and implemented. This will help in faster liquidation of standing pillars thereby reducing the fire risks and enabling extraction of the lower seams. These seams cannot be extracted at present due to standing coal reserves in upper seams.

- Mica-based and polymer-based sealants have been developed and applied in underground mines for prevention of the leakage. The field trials indicated that by application of the sealants, the leakage is reduced to 10 per cent.

- In order to obviate use of cumbersome coal cutting machines, an Auger-cum-Drill has been received at a colliery site and extensive trials will be given during coming months. Success of this equipment will substantially reduce the cost of blasting as well as result in increased production and productivity.

- An ash spectrometer using gamma source (Americicium 241) has been developed. Arrangements are being made to make the system on line.

- Coal blocks using inferior grade slack coal have been developed. A demonstration plant is being set up at Cantonment Area in New Delhi to demonstrate the process of making coal blocks to army authorities.

Some notable developments in underground mining are: introduction of mechanised sub-level open stopping method with ring hole drilling; use of trackless mining with decline at Khetri; large diameter blast hole stopping; introduction of cable bolting at Surda; use of deslimed tailings for cut and fill stopping by Hindustan Copper and Hindustan Zinc which have enabled the production to be raised from 800 tonnes/month (using conventional room and pillar stopes) to 6,000 tonnes/month; increased application of rock bolting and use of electrically operated load-haul-dumpers (LHDs).

Mining of thick coal seams by underground methods poses a major challenge in India. There are some 20,000 million tonnes of proven reserves in seams over 4 m thick and another 1,000 million tonnes in 8 m thick seams which are already developed in pillars. Techniques for exploitation have been examined and detailed technological solutions are currently available for locations, such as East Kenduadih, Pipradih, Parasia and East Katras. Surface mining as at Mukunda Opencast have solved the problem partially. The Central Mining Research Station (CMRS) has formulated a proposal for the extraction of a 36 metre thick, moderately inclined V-seam in the Central Chasnala block using cross-slicing method. For improving the recovery of thick coal seams with developed pillars, proposals have been mooted using wide stall and Talcher methods. Other thick seam methods being considered include working the 8 metre thick Kenda seam with sub-level caving, use of descending, slices at Nandira Colliery and hydraulic mining at Baragoloi Colliery for extraction of 18 metre seam.

Iron

The involvement of India in the international iron ore trade is evident from the development that has taken place in the fields of exploration and exploitation of iron ore deposits in India. In the field of exploration, from simple geological investigation methods, India today uses sophisticated techniques including computerised geostatistical evaluation of iron ore deposits for estimation of reserves and grade, thereby increasing the reliability of data base. Advanced geostatistical methods are now being used along with mathematical modelling of the deposits to be developed for exploitation to produce different products of iron ore to meet stringent specifications conforming to the buyer's requirements. Depending upon the nature of the deposit, whether it is simple or complicated, diamond ore drilling has become a normal standard. In addition to the above, comprehensive ore dressing and benefication tests and pilot mining are carried out.

Similarly, the development that has taken place in the method of mining is also amazing. Setting up of large integrated steel plants along with captive iron ore mines and the setting up of the National Mineral Development Corporation in the public sector as the premier organisation in the field of iron ore mining has catapulted iron ore mining from a largely manual semi-mechanised forms to large scale open cast mechanised methods involving elaborate ore-processing and handling arrangements with the construction of the massive Kudremukh magnetite mine with a capacity of 22 million tonnes per year.

Mechanised mining of iron ore has come of age. From a state of float-ore mining, India has passed through the stages of semi-mechanised and mechanised mining to the age of computerised mining wherein the different mining operations are carried out by preprogrammed computer-techniques ensuring optimum level of blending of different grades of ore to achieve the desired products.

India has not lagged behind in availing all the modern facilities and techniques available in the field of mineral dressing. Though most of the Indian iron ores barring the Kudremukh magnetite ore are based on high grade hematite deposits and may be acceptable as direct shopping ore, the majority of the hematite iron ore mines in India adopt ore processing methods. Stockpiling and loading of ores have also been fully mechanised to take maximum advantage of blending techniques and many of Indian iron ore mines can boast of controlling the variations of iron and other constituents like silica and almina to a negligible per cent. Rapid analysis techniques are employed to ensure effective quality control at every stage of the operation.

With all the above advancements that have taken place in the iron ore mining, industry today, India is well poised to produce different kinds of iron ore products, i.e., those with iron contents varying between 67 per cent and 58 per cent to high grade and low grade iron ore concentrates. These can be custom-made to suit the requirements of the consumer industry. Continuous research and development studies are invariably made to improve the specifications and to realise products which may give maximum benefit in iron and steel making with distinct advantage of energy conservation.

Today, India is totally self-sufficient in the fields of planning, engineering and construction of mines. The MMTC has developed expertise in planning and construction of opencast iron ore mines with a capacity of 5-6 million tonnes per annum. Even the large scale Kudremukh Iron Ore Company Limited utilised indigenous skills to a large extent and many of the detailed drawings were prepared by Indian agencies like the MECON and state enterprises like HCC, BEML, NAMC.

Back up research and development facilities have also been established to a very large extent. The R&D laboratory of MMC, NML, Indian Bureau of Mines, RRL, etc., are set up on the most modern lines with latest techniques and sophisticated equipment to carry out different types of ore dressing and benefication tests. Today such R&D activities like flow ability of iron ore fines, designing of storage bins and pipeline transportation studies are carried out apart from normal plant improvement and quality appreciation studies.

The occurrence of iron ore deposits and development of mines in India have necessitated creation of related infrastructural facilities especially for movement of the ore from hinterlands to the ports of exports. This aspect has been given special attention by the Indian Railways which has developed a broad network of rail system.

In addition to both rail and waterway transport, India has also developed the most advanced technique of slurry transport which envisages the transportation of iron ore fines in the form of slurry. In the Kudremukh iron ore mine, the iron ore concentrates are transported through pipeline over a distance of 67 kms which has a capacity of 7.5 million tonnes. Plans are already on hand to develop a similar system for transportation of iron ore concentrates from the Bababudan magnetite ore deposits.

Indian iron ore possess excellent qualities like high iron content with very low sulphur and phosphorous contents a favourable silica alumina ratio, high reducibility, low decrepitation and thus form ideal feed material for blast furnaces and direct reduction plants, etc. The enormity of reserves coupled with all round development in exploration mining, benefication, transportation and loading ports are definite pointers that India will be one of the most dependable sources for the future needs of iron ore in the international market.

Today, India is in a position to extend necessary assistance and technical know-how in setting up integrated and mini-steel plants. This will be an added advantage for some of those countries who do not have resources of iron ore or possess the technical know-how to set up their own steel plants.

Rural Technology and Environment Management

'RURAL TECHNOLOGY' is characterised essentially by its inherent capabilities of creating gainful employment, increasing productivity, recycling wastes and byproducts and producing value-added items, thereby augmenting productive work and enhancing income in rural milieu. Human welfare through better housing and sanitation, community services, elimination of drudgery especially among the womenfolk, promotion of decentralized techno-economic systems, particularly for the remote areas and such other aspects of human development are also catered to by the technologies generally grouped under 'Rural Technology'.

The National Research Development Corporation (NRDC), Council of Scientific and Industrial Research (CSIR), Indian Council of Agricultural Research (ICAR), Department of Science and Technology (DST), Khadi Village Industries Corporation (KVIC) and the Department of Rural Reconstruction have done considerable work on the generation, development and demonstration of new technologies in the field of food, water, sanitation, environment, human settlement, roads and communication, energy and natural resources. The area, in which a number of appropriate technologies have been developed are: leather industry, pottery making, processing of cereals and pulses, production of matches, fireworks, soap making hand-made paper, bee-keeping, coir and other fibre making industries, biogas, lime manufacture, blacksmithy and carpentry.

Traditional method to filter water through beds of sand, gravel and charcoal to remove suspended impurities followed by boiling to kill harmful bacteria is not only time consuming but costly too. The method has been simplified by Regional Research Laboratories.

The Indian scientists have developed low cost but equally effective alternative solutions to the capital intensive drinking water technologies.

They have developed a number of techniques to make water potable and free from disease germs like bacteria, viruses, protozoa and worms besides being physically clean and acceptable in taste.

The National Environmental Engineering Research Institute (NEERI), Nagpur, has carried out a critical evaluation of selected rural water supply schemes in eleven states and has worked out project proposals for rural water supply covering planning, design, construction, operation and maintenance.

In rural areas where ground-water available is of good quality and at reasonable depth, it is drawn by means of hand-pump, tube-wells of appropriate design. As this water stands filtered by nature, normally no treatment is given except chlorination for safety. A compact water-treatment plant suitable for rural conditions has been designed and developed by the NEERI. The plant has three concentric cylindrical compartments, the innermost flocculator is equipped with paddles. The alum solution is fed by a constant-head gravity device. The flocculated and settled water is filtered. A bleaching-powder solution is added to the flocculated water before it flows into the sedimentation basin. As a result, there is adequate contact time for disinfection, and the sedimentation basin and filter area, free from organic fouling.

The plant was operated continuously for a year and data were collected using Kanhan river water with a turbidity range of 20-1,900 NTU. The alum dose ranged from seven to 200 mg/litre. The physicochemical characteristic of treated water conformed to the standards for drinking water. The skill available in the villages was adequate to operate and maintain the plant. The power consumption was nearly one unit per cubic metre of treated water and the estimated cost of treatment per cubic metre was about Re. 1.00.

The Structural Engineering Research Centre (SERC), Ghaziabad, has developed economical and lightweight ferrocement water tanks of capacities ranging from 270 to 20,000 litres to provide drinking water to rural areas. These tanks can also be used for storing water required for sanitation. Ferrocement, a highly versatile form of reinforced mortar, consists of closely spaced layers of wiremesh reinforcement impregnated with a rich cement-sand mortar. It is possible to cast ferrocement elements with a thickness of as small as 1 cm. It possesses high resistance to cracking and unlike steel structures also has high corrosion resistance.

Water tanks developed at SERC are cylindrical in shape and are assembled with prefabricated components. Tank walls can be produced by using either of the two casting methods developed at the institute. The methods are: semi-mechanised process for producing cylindrical units; and casting segmental shell elements and assembling these into cylindrical units. While the first process is suitable for producing tanks of up to 2,500 litres capacity, the later process is suitable for tanks to be used in hilly areas or villages where transportation is difficult and also for tanks of larger capacity than 2,500 litres.

The charcoal water filter, developed by NEERI, is an effective technique for the removal of solids, suspended materials and other harmful bacteria. It can filter sufficient drinking water for one family.

The Central Glass and Ceramic Research Institute (CGCRI), Calcutta, has developed water filter candles, which can be fitted to domestic water containers, including earthern pitchers. The candles remove harmful bacteria from the raw water. The Regional Research Laboratory (RRL), Jorhat, has developed a process for the manufacture of domestic water filter candles that can be fitted to domestic water containers, including earthern pots and plastic buckets. Suitable grade of clay, a binder clay and bacteria inhibitor are grounded separately and passed through a sieve. These substances are then blended and mixed with aqueous solution to obtain slurry. Candles are then prepared from slurry in moulds, dried and baked. This technology has been licensed to 16 parties and some of them have gone into production.

A chlorination pot for wells, which effectively chlorinates water in open dug wells up to three weeks, has been developed by scientists of NEERI. A pot of seven to eight litres capacity is taken and 6-8 holes of half a centimeter diameter are made at the bottom. The holes are covered with stones or pebbles of 2.4 cm size. This layer is covered with pea gravel of smaller size. This layer is covered of bleaching powder and three kg. of coarse sand is prepared and spread over the pea gravel. Finally, the pot is fitted with pebbles or stones up to the neck. Now the pot is lowered in a well with the help of a rope approximately one metre below water level. The pot is enough for a community well where 900-1,300 litres are drawn per day. This gives adequate chlorination for 10-15 days. Wells with higher draw-off rates need two chlorination pots.

The NEERI has also developed chlorine tablets and ampules or disinfecting water at the household level, particularly in rural areas. The health department ot some state governments are stocking these tablets for free distribution in rural areas and those under epidemic. At present there are ten firms manufacturing these tablets and ampules.

For defluoridation of drinking water, NEERI, Nagpur, and Tamil Nadu Water Supply and Drainage Board, Madras, have developed two methods independently. Under the Nalgonda technique, an alkali (lime, soda ash or sodium bicarbonate), alum and bleaching powder is added to the water stored in a container. A tap is fixed at 3.5 cm from the bottom. Raw water to be used for drinking is put in the container and chemicals are added in adequate quantities. The water is stirred for about ten minutes. The floc formed settles in an hour. The clear supernatant can then be drawn out by opening the tap. The sediment is discarded. This technique has been demonstrated in some villages of Andhra Pradesh, Tamil Nadu and Rajasthan.

For treating 50 litres of raw water the cost would be 2-10 paise depending upon the concentration of fluoride to be removed. The TWAD technique, developed by TWAD, Madras, can completely remove fluoride from the water. The plant is so designed that raw water pumped out of the well is conveyed through a pipe and doses of lime and alum are added to it in stages from containers kept above the water level. The water, mixed with these chemicals, then goes down to another pipe and enters from below into a circular tank with a conical bottom filled with river pebbles. The treated water is tapped from top of the tank.

The important feature of the technology is that the flocs formed by the interaction of lime and alum with water settles down as a uniform layer above the pebbles instead of floating. This sludge blanket thus formed creates the proper conditions for the removal of flouride. The TWAD technology is also successful in precipitating the aluminium derived from the alum. Thus, while improving the efficiency of fluoride removal, it helps in finally treating water that is also free of aluminium which otherwise would pose a health hazard if present in more than the permissible limit. The TWAD scientist have set up a pilot plant near Poonamalee, close to Madras, which has achieved 100 per cent success.

A number of techniques to remove salinity from brackish water making it potable has been developed by the Central Salt and Marine Chemical Research Institute (CSMCRI), Bhavnagar, and Bhabha Atomic Research Centre, Bombay. Desalination is now being accomplished in the country mainly by distillation processes, membrane processes, electrodialysis and solar distillation techniques. Work on solar distillation has been conducted at CSMCRI, National Physical Laboratory, New Delhi, and Defence Research Laboratory, Jodhpur. A 1,000 litres per day capacity was constructed by CSMCRI in Kutch.

NEERI, Nagpur, has also developed a test kit for measuring residual chlorine which is used either in the form of gas or as solution in water or as bleaching power for disinfection of water supplies. Being very active it reacts with most of the impurities in water including disease causing micro-organisms. Thus residual chlorine in water indicates fulfilment of complete chlorine demand and the presence of excess for taking care of any later contamination. The kit helps in ensuring an optimum level of 0.2 ppm of chlorine in water to ensure complete disinfection.

During the sixth plan period over 1.92 lakh problem villages were given facilities for safe drinking water. In addition, 47,000 non-problem villages were also covered. However, figure of coverage of problem villages during the sixth plan period appears prima facie impressive, but it may be mentioned that substantial portion of the coverage was only partial in future.

To eliminate the drudgery involved in making "donas", a simple machine to make cups or plates from various kinds of leaves has been developed by CFTRI, Mysore. Various models of improved chullhas (stoves) have been developed. They could be made with locally available mud mortar, cattle dung, sand straw, red clay, A.C. pipes, metallic damper and metallic hool. The new chullhas are 30 per cent more efficient than the traditional ones.

The RRL, Jorhat, has developed a paper slate which proved a good substitute for the conventional costly stone slates. The paper slates are light, unbreakable, cheap and do not lose abrasiveness quickly. The raw materials required for making the slates are paper board and some chemicals.

Several indoor and outdoor storage bins have been developed and tested by many institutions in India including Central Building Research Institute (CBRI), Roorkee, Structural Engineering Research Centre (SERC), Ghaziabad, Indian Plywood Research Institute, Bangalore, and Indian Grain Storage Institute, Hapur (U.P.). These bins could be made of mud, bamboo, earthenware, masonry metal and wood individually or in combination.

The CFTRI, Mysore, has also developed following processes to control pest: (1) durofume process for protecting commercial stock of food grains; (2) pest proofing of jute gunny bags used for storage of food grains by means of a portable machine (400 bags/hr); (3) low-cost fumigant tablets called 'Minifume' (one tablet costing about Re. 0.60 is enough to treat 100 kg of foodgrains); (4) an integrated technique of eradication of domestic rats involving fumigation of rat burrows and combined use of repellants, attractants and poisoned baits.

The RRL, Bhubaneshwar, has developed a 'food preservation flask', in which cooked food can be preserved for a period of three days without refrigeration.

The efficiency of the traditional bullock cart is low and despite this it is being used as a means of rural transport in the country. Many new designs have been developed to increase its efficiency and reduce the strain on the animals. Major innovations in the new bullock carts are the hand operated shoe-type brakes with spokes for increased load carrying capacity and bearing, for smooth running. Two such stub-shafts eliminate the axle shaft to facilitate easy turning.

Low Cost Housing

About 26 research institutions in India have evolved more than 52 new construction techniques and materials which can reduce the cost of construction as well as conserve scarce and costly inputs like cement and steel.

A number of new construction techniques have already been incorporated by the National Building Organisation (NBO) in its experimental housing project. They are also being adopted by various construction agencies in the country. These include single brick thick load bearing walls for up to five storeyed residential buildings, under-reamed pile foundation, precast RCC roofing system and precast lintels.

The Central Building Research Institute (CBRI), Roorkee, has developed a technique known as under-reamed piles for laying foundations in black cotton soil areas whose soil bearing capacity is low and subject to alternate cycles of swelling and shrinkage. It has developed a technique for making improved roofs from thatch. The thatch could be made of paddy, straw, coconut leaves of palmyra leaves or reeds. The life is four to five years, as against about a year of the traditional made thatched roof. The institute has also developed a non-erodable plaster for protecting mud walls against rains. It would greatly help villagers in reducing their house maintenance costs. Recently RRL, Trivandrum, has developed a mixture of urea and diammonium hydrogen phosphate which proved to be a good fire retardant for coconut leaf thatch used as a roofing material in the coastal areas. It has also been found that a combination of copper sulphate and phosphorylated cashewnut shell liquid not only enhance life of coconut leaf thatch but also provides fire retardant property. Aluminium phosphate has also been found to impart fire retardancy to thatch.

The CBRI and RRL, Jorhat, have developed a process for manufacture of cheap roofing made of paper sheets which are light, strong, fire resistant, non-absorbant and unbreakable. It is easy to transport and install.

The construction of under-reamed piles is very simple and it requires equipment like auger boring guide, earth auger, under-reams, wheel barrow and concrete funnel. These are board concrete piles having one or more enlarged base towards the bottom. The principle involved is to anchor the building by means of these piles at a depth where the soil has a nearly stable moisture content during the various seasons of the year.

These piles can be successfully used for machine and factory foundations and foundations of transmission towers. The piles have been standardised to avoid inconvenience in the construction. The main diameter of the piles ranges from 20 cm to 45 cm and the length from 3 m to 8 m. The diameter of the under-ream bulb is generally two and a half times that of the piles. The minimum spacing of the under-ream is 1.5 times, the diameter of the under-ream itself. A reinforcement case is also provided through the length of the pile.

Under the single-brick thick load bearing walls, techniques which use better quality of bricks, and improved methods of construction, the thickness of walls of four storeyed buildings could be significantly reduced resulting in economy in cost and consumption of materials.

Appropriate materials for roofs which contribute 30 to 40 per cent of the total cost of construction have been developed by various institutes in the country. The Regional Research Laboratory, Trivandrum, has developed a process which extend the life of coconut leaf thatch from one to four years. A separate process has also been developed at the laboratory which makes coconut leaf thatch fire-retardant for short term uses. It has been found that a combination of copper sulphate and phosphorylated cashewnut shell liquid (CNSL) not only enhances life of coconut leaf thatch but also provides a fire-retardant property. Aluminium phosphate has also been found to impart fire retardancy to thatch.

The CBRI has developed good quality clay tiles which increase the life of roof. The use of cement and steel can be avoided by making the roof with the clay tiles. Methods to manufacture asbestos or G.O. or aluminium corrugated sheet which are light in weight and economical in cost, have been developed. But the disadvantage of such roofs are that these get heated up quickly. Asbestos sheets are brittle and these get rusted in humid areas. The CBRI has also developed cement-coir-corrugated sheets for roofing which do not suffer from these defects.

The NBO has developed a method for manufacturing of corrugated sheets from waste materials like scrap paper, bagasses, jute wastes and coconut fibres. These sheets have good thermal insulation properties and are water proof, flexible and light in weight. They are not susceptible to corrosion and leakage and are relatively safe against fire and are not brittle like asbestos sheets. In this type of roofing use of cement and steel is practically nill. It has been recommended to be used in the areas where the temperature does not exceed 40°C.

For flat roofs, several systems like RC channel units, RC plank and joist system, doubly curved tiled roofing, precast circular units, L panel roofing, cord unit system, precast wall, shell unit and battens and hollow block system have been developed by various institutes which cut down consumption of steel and cement ranging from 5 to 20 and 15 to 30 per cent respectively.

The CBRI and RRL, Jorhat, have developed a process for the manufacture of cheap paper roofing sheets which are light, fire resistant, low waste absorption, high strength, no breakage in transport and easy to install. These sheets are comparatively much better as against the commercially available one.

In search for substitute of cement, the Karnataka State Council for Science and Technology (KSCST), Bangalore, has found that starch solution and jaggery syrup could be substituted for the costly cement and lime for construction purposes. The jaggery syrup, prepared by boiling waste jaggery with water till it acquires stickly consistency, can be mixed with red soil and then pressed into solid blocks. Similarly starch solution prepared by baking maida flour in water can be pressed into blocks. These blocks were found to be erosion resistant after thorough drying. It has also developed pre-fabricated light weight roof panels using bamboo, paddy husk, soil and cement.

A process of hydration of lime has been developed which makes available hydrated lime in dry form, standard quality and ready to use condition as in the case of cement. It can be stored in bags for 6 months without any deterioration. It can be used either alone or in combination with cement or clay pozzolana.

A new process of production of clay pozzolana produced by grinding brickbats has been developed in which clays of suitable specifications are calcined to the optimum temperature and then grind to fine powder as required by the Indian Standard Specifications. The processes have been developed for production of clay pozzolana by using down draft kiln by the Central Road Research Institute.

In order to improve quality of timber, the Forest Research Institute, Dehradun, has developed techniques for seasoning of timber which is essentially a drying process. It decreases weight and generally increases strength and helps in retension of shape.

Investigations carried out in Research Laboratories have shown that flyash, a fine residue obtained from thermal power stations, can be utilized in various form as building material. It can replace cement 20 per cent by weight without adversely affecting the strength of concrete.

The College of Military Engineering, Pune, has fabricated houses which essentially consists of prefabricated RCC frame work, precast ferrocement, roof panels, half-brick thick walls and brick paved floor. Cost of construction comes to about Rs. 300 per sq metre.

The CBRI has also conducted intensive studies on planning, design and construction aspects of the houses during the last four decades with a view to obtaining optimum utilization of space, increase in functional efficiency and reduction in cost of construction. Based on these studies a single storey dwelling unit for a family of four members has been evolved.

The design is said to be structurally sound, functionally efficient, aesthetically appealing and offer an economy of about 10 per cent in the overall cost. The plinth area of the house is 48.6 sq.m. The estimated cost of construction of the house was around Rs. 45,000.

Under the experimental housing scheme, NBO has tried out new buildings material and techniques in 42 projects costing Rs. 30 million in different parts of the country. The techniques and materials tried out were under-reamed pile foundation, precast RCC roofing system, thinner load bearing brick walls and use of high strength deformed bars.

Mushroom Culture

The ICAR and RRL, Jorhat, have improved a method for cultivation of edible mushroom. Under the method paddy straw is cut into pieces and soaked in water for about two days. The straw is drained and filled in polythene bags. After incubating in bags in a room, mycelium is innoculated and the bags are kept in a properly aerated room. The bags are regularly irrigated and the mushrooms start appearing after about five days.

A simple high-efficiency wood burning stove has been developed by the Central Power Research Institute, Bangalore. The stove consists of a cylindrical chamber closed at top and the bottom with slotted plates of specially evolved pattern a grate is fitted inside the chamber slightly above the bottom slotted plate.

The dimensions of the plate and the chamber have been carefully worked out to achieve maximum combustion. An aluminium sheet linings provided in the chamber to reflect heat towards the centre of the combustion chamber and to minimise heat loss through radiation from the walls. These design features have boosted its thermal efficiency to over 30 per cent.

Farm Machinery

In the area of farm machinery, several useful machines and implements have been produced including bullock drawn sweeps, chisel plough puddler, manual and animal drawn seed cum fertilizer drill, power tiller operated paddy harvestor, tractor oriented reaper binder and multicrop thrasher. Besides, several tools have been further improved namely hand holes, ploughs horrows and cultivators. In the case of processing equipment several innovations have taken place. Mention can be made of equipment like grain dryers for cereal crops, groundnut decorticator, sun-flower and groundnut cracker. Several designs of cowdung and biogas plants have been developed and single technologies have worked out to recycle agricultural wastes.

Several models of solar cookers including simple hot box type solar cookers with the reflector, solar oven with multiple reflectors and solar concentrators have been developed under a scheme, sponsored by Commission for Additional Sources of Energy. Under the demonstration and field trials programme in this area, systems like water heater and dryers, wood seasoning systems and pumps are being installed.

Besides development of appropriate technologies to rural masses, a number of schemes relating to the transfer of relevant technologies for landless labourers, artisans, small and marginal farmers and tribal communities like setting up of krishi vigyan kendras, the lab to land agricultural programmes of the ICAR, polytechnology transfer centres of the CSIR, training of rural youth for self employment (TRYSEM) of the Department of Rural Reconstruction and Health for all programmes of the ICMR are being implemented. The NRDC and KVIC have been able to take the relevant technologies to rural areas with the help of its regional offices or centres located all over the country.

The Indian Jute Industries Research Association, Calcutta, has developed a technology for suitable binding jute/wool and jute/viscose to make woollens.

The Central Electro-Chemical Research Institute (CECRI), Karaikudi, has made a breakthrough in dry cell technology using indigenous raw materials and machinery. The cell produces are comparable to other cells marketed in the country.

The RRL, Jammu, has developed a process to produce fibre boards from pine needles. Packing cases made of these boards have been found useful for packing and transporting fruits over long distances. These packings are cheap and durable and easy to assemble or dismantle.

Although over 450 rural technologies developed in the country have been adopted by villagers, there is more to be done to make innovations and inventions a way of life in rural areas.

Rural Roads

The rural road building engineers have progressively improved and standardised various techniques of building roads in rural areas and are applying them to field conditions. At least six economical and efficient techniques of soil stabilisation have been standardised by engineers of the

Central Road Research Institute (CRRI), New Delhi. Many handy and energy-saving tools have also been designed and fabricated by them.

Besides there are more than 30 institutions, big and small, working in this direction and have achieved varying degrees of success and sophistication of approach and technologies. The Central Road Research Institute is the largest and the best equipped organisation with rich experience and achievements behind it.

Before constructing a rural road, the soil on which it rests has to be treated and stabilised so that potholes do not appear and spoil the surface. The surface may also crack on unstabilised soil, making movement of vehicles virtually impossible. CRRI engineers have standardised six techniques of soil stabilisation, namely, mechanical, lime, cement, lime-flyash, bitumen and two stage stabilisation.

These techniques vary according to soil conditions and materials available locally because cost is the main constraint in rural roads construction. Mechanical stabilisation is applied to soils containing sand, moorum/gravel with missing fractions and clayey soils. Missing fractions are blended (e.g., clay with sand) so as to produce a mass of maximum possible density end with plasticity within limits. Too much plasticity is not desirable—it makes the subgrade weak.

Lime stabilisation is the most preferred treatment for its free availability and cheap price. Black cotton soil in Maharashtra, Andhra Pradesh, Madhya Pradesh and Uttar Pradesh poses a problem for road construction as the soil shrinks and cracks during dry spells. This would crack the road surface as well. But if only five per cent of lime is added to the soil, a chemical reaction takes place, and the soil becomes ready for laying roads. CRRI engineers are using this technique for stabilising soils in these states. This works out to be very cheap and lasting. For this purpose, lime is dehydrated from reacts with clay minerals in the soil to cause immediate reduction in plasticity because of cationic exchange, flocculation and agglomeration. Lime is also used for long term chemical reaction with clay minerals to produce cementitious products which bind the soil for increased strength and stability.

In the cement stabilisation techniques hydrated cement products bind soil particles, the strength developing depending on the concentration of cement and the particles. But, cement treatment of soil is everywhere, until it becomes unavoidable, such as in the case of granular soil without high concentrations of organic matter.

Clayey soils and soils with medium plasticiy are stabilized by the lime-flyash stabilisation techniques. Lime reacts chemically with silica and alumina in flyash to form cementitious compounds which bind the soil.

Bitumen stabilisation is not the prefered mode of stabilisation for its excessively prohibitive cost factor although it is settled beyond doubt that it is a superior material making the road impervious to water and many environmental factors.

Soil stabilisation forms the foundation of road building and thus has a special place in the technology. Road engineers have very skillfully and economically used locally available materials to stabilise soil for Indian village roads. Kankar (small pebbles), moorum, laterite, dhandhala, gravel, lime and other local materials mixed in right proportions with soil have been found to stabilise soil very efficiently, especially since the roads are meant for bullock carts with damaging solid wheels.

While building roads for solid-wheeled carts, the fact that has to be kept in mind is the destructive nature of cart's wheels. Because of very localised stress and pressure on the road and sharp-edgeness of the steel lined wheel, deep tracks develop on the surface and finally the road given way. For this purpose, the thickness of the material applied has to be appropriate to withstand the onslaught. CRRI engineers have worked out a formula which will tell exactly what should be the thickness of the material used.

The contact area of the steel-rimmed tyre on the road depends on the extent of wheel load, width of tyre, road camber, degree of self alignment of wheel, axle system, and the flexibility of degree of yielding of the surface. Based on these parameters CRRI engineers have plotted a design curve which says that for most of the soil, the required pavement thickness should be around 9 inches. This is being applied throughout the country with successful results.

Pavement thickness being a very important consideration in road building, CRRI technologists have worked out an index which indicates the exact thickness of the pavement required depending on the stress and load bearing capacity of the soil and materials used. It is a very straight forward curve which would immediately tell the engineers what should be the thickness of the pavement to carry a given set of vehicles on a particular soil type. According to the stress, bearing capacity of the soil, the additives used to stabilise it, the upper layers of the roads and the types and average number of vehicles plying the route it is then decided what the thickness should be. Soil and subgrade compaction are also important factors in rural road construction. The more compacted the material the better its ability to withstand stress and load. CRRI scientists have standardised methods of soil compaction on the basis of materials, soil, equipment used and the pavement thickness required.

Building rural roads is a necessity but it should be with an eye on economy and usefulness. CRRI scientists, after studying dozens of villages and roads connecting them, their commercial status, agricultural development, proximity to market, highways and main roads and towns, as well as their topography have designed on overall approach to building roads for their use which would best serve their interest and be economical at the same time. CRRI supplies precise information on how to connect a village with a township or a market centre and how to route it.

Such models are of great use in preparing master plans for rural development at the national level, taking the district as the basic unit.

Quality control being essential for ensuring proper construction and serviceability of roads, CRRI has developed a wide range of easy, quick and efficient tests that can be conducted on site. The tests, like evaluation of soil type and mixture content, are simple enough to be handled by an undergraduate with preliminary training in handling the equipment.

CRRI engineers have also designed precast concrete paths for rural roads in which two parellel running concrete pavements are laid to provide a hardy surface for carts to ply.

The institute is conducting tests on the quantitative effects of various compositional factors on the strength and deformation characteristics of granular mixes. This study is important as the requirements of bitumen, a petroleum based material, have to be cut down for economy in road building. Equipment and test procedures have been developed and devised making possible the comparative evaluations of granular mixes under controlled conditions.

In western Rajasthan besides the fine dune, sand and the kankar/dhandhala here and there conventional construction material as well as water are not generally available locally. Though initial design and successive trials under static and repetitive loading, design has been optimised for medium intensity of traffic. The design consists of ribbed hexagonal precast concrete blocks with convenient arrangements for interconnections and load transfer.

Improvements in bullock carts have also been effected at the CRRI. The institute developed a wheel tester for testing wheel designs, wheel axle system and bearings. A procedure was developed for the assessment of contact stresses on the pavement due to solid wheels and concepts were developed for pavement designs based on solid wheel traffic in rural areas.

In more recent years attention has been given to the development of low cost bearings as well as flexible element which improve the contact between the wheel and the travelled surface of changing cross profile and this would reduce the tracking effort.

Under a sponsored scheme of the Ministry of Transport, bullock cart prototypes with innovative energy-saving designs were fabricated and distributed to farmers in and around Delhi and in the northern states of the country for actual field trials, and as a result some improvements have been made in cart design.

Landslides pose a grave danger for road builders as well as for road users. The evaluation and testing of landslide prone areas and soils is regularly done and many instruments have been indigenously fabricated for such tests. Some of the instruments so developed are the composite differential settlement cum tilt meter and the remote control hydraulic settlement gauge. Other instruments which have been developed for this purpose relate to the fabrication of a slope indicator for monitoring small ground motions in earthquake projects and hillside rocks.

In the process of evolving suitable and economical specifications for rural roads, CRRI scientists found through laboratory research and field experimentation that soft aggregates like brick ballast, kankar, dhandhala coral stone could be used instead of costlier stone aggregates for rural roads.

Keeping in view the non-availability of power driven road rollers in villages, CRRI engineers developed easily fabricated and ferried road building devices. A collapsible animal drawn road roller so developed comes in very handy. It consists of a wooden box mounted on the metallic roller. The box is empty but when filled with rocks or any other heavy material works as a light roller and is drawn by an animal. Another roller is even lighter. It is made of a hollow but thick-bodied drum. When filled with rock it works as a roller. It certainly takes more rounds than a power roller would, but there are thousands of villages especially in hilly and marshy areas where power driven rollers just cannot reach. Here such rollers can do the job just as efficiently, and are far cheaper.

A water bowser designed and fabricated by CRRI engineers is actually an improvised device. Five to six big metal drums are mounted atop a cart. They are connected together by means of pipes. A perforated pipe at the rear end of the cart sprinkles water on the road while it is under treatment and rolling. It is very cheap and is used where mechanical or power driven pumps are not available.

CRRI scientists have also developed and fabricated an animal drawn aggregate spreader for roads. It is part mechanical and part manual. It spreads the aggregate mix uniformly and works much faster than man but not the mechanical spreader.

Road building technology for rural areas is fairly improved in India and future developments will strengthen it further. But a nagging issue is the limited number of villages in the country which have serviceable all weather roads. More than seventy per cent of the over 780 million Indians live in

600,000 villages dotting the entire Indian landmass, but only one-third of the villages have been provided with all weather roads. Estimates are that Rs. 25,000 million will have to be spent to give every village an all weather road by the turn of the century.

The avowed aim of the Government to construct 27,00,000 km of roads by 2000 AD calls for a massive organisational structure and the easy availability of funds, materials and expertise. About 10,00,000 km of rural roads need to be built to let nearly 15 million animal drawn carts in the country ply and carry most of the grain and material and ferry cattle and people from one place to another.

Environment Management

In the field of environment management, Indian scientists have developed facilities for management of radio-atomic wastes and chemical effluents of atomic power plants, reclaimed waste water, and supplied cheaper piped gas by recycling urban wastes.They have also generated electricity from municipal wastes and undertaken the gigantic task to clean the Ganga, the symbol of India's age-long culture and civilisation. The main thrust of the Ganga action plan is to purify the river to prevent the discharge of effluents with a high pollution load by renovation of all existing sewage pumping and treatment plants and installation of new plants.

Works in this area has been on air quality monitoring and pollution control, water chemistry and treatment, solid waste management, rural sanitation and epidemiology. The Department of Environment (DOE) lays major emphasis on environmental and ecological research, environmental impact assessment, monitoring of environmental quality, setting up of environmental information system, restoration of fragile ecosystems, preparation of an inventory of ecological resources, soil and water conservation, forest conservation and aforestation, social forestry, economic and industrial plantations, energy plantations, drinking water supply and sanitation.

Waste water reclamation through aqua-culture, optimum utilisation of domestic and industrial waste water in agriculture, a detoxification of phenol and cyanide bearing waste by biological methods have been the major areas of emphasis at the National Environmental Engineering Research Institute (NEERI), Nagpur.

Studies on seweage and industrial waste treatment and its utilisation have been taken up by the NEERI for over 250 industries manufacturing synthetic drugs, pharmaceuticals, pulp and paper, straw board, rayon, chemicals, high explosive and fertilisers. Designs for appropriate mechanical compositing plants have been developed by NEERI after careful characterisation of solid wastes of over fifty major cities.

One such large size plant for urban waste recycling is already existing in the country and is being operated successfully at Okhla near Delhi. The plant comprises 15 digestors connected to gas collectors. The total gas generation from the plant is about 0.6 million cubic feet per day, having a heat value of 700-800 BTU per cubic feet. The gas is being successfully piped to about 800 households spread over an area of four kilometres. The cost of investment in sludge gas is about 50 per cent cheaper than the ordinary LPG cylinder gas.

Based on the successful experience and considering the potential of sewage sludge treatment systems as a renewable energy source the government has assigned due importance to this area. One such project has been commissioned at Padrauna in Uttar Pradesh, and plants are under construction at Ayodhya in Uttar Pradesh, Keshaopur (Delhi) and Bhopal (Madhya Pradesh). Experience from these pilot projects is expected to provide a basis for extending the activities to other potential cities in the country.

The combustion of refuse solids converts the combustible components to inert substance generating heat and resulting in 75 per cent reduction in volume. The process is known as incineration. About 25-45 per cent of heat becomes surplus after supporting combustion and could be utilised as a source of energy. Though conventional incineration is the usual method adopted for disposal of urban wastes elsewhere, only about 13 per cent of the total urban waste is processed using this technique. The efficiency and output of the incineration is, however, low and presents problems like requirement of large incinerations, firing devices (refuse being voluminious) requirement of storage facilities which may lead to purification of organic matter and air pollution in the absence of proper control devices. Viable technologies have merged in the country for successful incinerators. In Delhi, the first pilot incineration plant which will process 300 metric tonnes of municipal solid waste per day of power generation has already started working. Such plants are likely to be set up in other cities like Calcutta and Madras,

Pyrolysis—chemical decomposition of carbonaceous material by that in the absence or in the controlled oxygen atmosphere—is another promising indigenous technology for resources recovery from solid waste. The process has the advantage of reducing the volume of waste to 80-90 per cent with minimum chances for air pollution and requires less land area. The product of pyrolysis and indirect gasification are fuel gas, mainly carbon monoxide, hydrogen, methane, carbon dioxide and charcoal.

Delhi and Maharashtra have taken up setting up of pilot plants based on the pyrolysis gasification technology for treating solid wastes. Perfection of this technology in Indian conditions and success of these pilot plants may open promising avenues for resource recovery from urban waste in the country.

A plant for detoxification of phenols through soil microbial cultures of an LTC plant in Andhra Pradesh has been set up by NEERI. Four slow sand filtration plants have already been set up based on know-how developed by NEERI.

While an anaerobic digestion technique using a special filter has been developed at the Central Leather Research Institute, Madras, to reduce the BOD content of tannery effluent, the National Institute of Oceanography, Goa, has found out suitable discharge point for treated effluents from port-based steel plants and fertiliser plant.

Epidemiological surveys have been conducted by the Industrial Toxicological Research Centre, Lucknow, to determine the health status of the working population to unravel existing as well as hitherto undetected health hazards to workers in specific industries exposed to cyanide fumes, lead poisioning in jewellery manufacture. Two bacterial strains for microbial degradation of plastics and other material used in the polymer industry have also been isolated by the ITRC.

The NEERI has taken up major research projects on analysis, assessment and chemical treatment of toxic discharges from phosphatic fertiliser and basic organic chemical industries, assessment of utilising effluents from copper, zinc and fertiliser plants and refineries and agricultural usage and impact of fugitive and stack emissions from selected industries such as fertilisers and cement plants on neighbourhood air quality.

Programmes on health problems arising out of exposures to environmental pollutants in industries especially synthetic dyes, pesticides, plastics, petrochemicals, metals and minerals are being undertaken by ITRC. Standards for thermal stress on industrial workers in an industrial environment are being evaluated at the Central Building Research Institute, Roorkee.

The Bhabha Atomic Research Centre, Trombay, has completed construction of solid state surveillance facility at Tarapur for the interim storage of solidified high level radioactive waste packages produced in the waste immobilisation plant (WIP) at Tarapur. Facilities for management of radioactive wastes and chemical effluents at Tarapur, Kota, Trombay, Hyderabad, Alwaye and Kalpakkam are functioning satisfactorily. Experimental work is under way to estimate feasibility of deep geological formations for radioactive waste disposal.

While the Cotton Technological Research Laboratory (CTRL) in Bombay has designed and fabricated a biogas plant in which willow dust, waste material generated in textile units, is used as raw materials, the Central Building Research Institute, Roorkee, has developed a system to dispose waste water near the source point. The system consists of two chambers—an ash/silt tap chamber and filtration chamber. The first one is meant for water in which silt or ash will settle down and the other filled with brick aggregates for removal of the suspended or colloidal matter in the water. The drain waste so filtered flows into a bore hole for ultimate disposal.

A study conducted by the Central Soil Salinity Research Institute, Karnal, has revealed that use of untreated sewage water for irrigating vegetables is not good for health as vegetables may contain pathogens and toxic elements like lead, nickle, mercury and copper.

The potential of flora and fauna as indicators and containers of pollution, jointly taken up by ITRC and the National Botanical Research Institute, Lucknow, is being evaluated. Alcohol was extracted by the scientists of Indian Institute of Technology, Delhi, from distillary wastes.

Use of tannery effluents to grow water hyacinth for investigating the possibility of biodegrading toxic elements is an important ongoing project at the Central Leather Research Institute, Madras.

With the creation of the Department of Environment in 1980, the Government of India has pursued nature conservation and management on a broader scale, than the time when the National Committee on Environmental Planning and Coordination was serviced by a small division in the Department of Science & Technology. This national level committee, created in 1972, was preceded by a committee on human environment set up in 1970.

The Department of Environment's functions cover wide ground, including coordination, policy planning, regulatory functions, conservation and promotion. To ensure effective performance by the department complementary work in several areas is being pursued. These include pollution control, environmental assessment, living natural resources, conservation, eco-development, environmental research promotion, environmental training, education and awareness of environmental law, society, environment interactions, coordination/liaison with state governments, environmental information, international cooperation, administration and finance.

Some legislations that are being enforced in the country are as follows: The Water Act (1974) the Water Cess Act (1978) The Air Act (1980) and the

Wildlife (Protection) Act 1972. Recently the government has enacted the Environment (Protection) Act 1986 to check pollution and conserve flora and fauna. It empowers any citizen to seek legal recourse against parties harming the environment.

The department has been working closely with some organizations associated with wildlife conservation. These include the Indian Board of Wildlife, the Zoological Survey of India, the Botanical Survey of India, the Indian Institute of Wildlife Management and the Delhi Zoological Park.

NEW CONSTRUCTION TECHNIQUES AND DESIGN CONCEPTS EVOLVED BY VARIOUS RESEARCH INSTITUTIONS

1. Central Building Research Institute (CBRI), Roorkee:
    - (i) Under-reamed pile foundation
    - (ii) Brick-on-edge cavity walls
    - (iii) Single thickness load bearing brick walls for 4 and 5 storeyed buildings
    - (iv) Improved method of brick laying and plastering
    - (v) Polythylene damp proof coarse
    - (vi) Stone block masonry
    - (vii) Light weight aggregate concrete blocks for partitions
    - (viii) Precast RC channel unit for roofing/flooring
    - (ix) Precast RC cored units for roofing/flooring
    - (x) Precast RC cellular units for roofing/flooring
    - (xi) Precast RC waffle units for roofing/flooring
    - (xii) Doubly curved tiles roofing system
    - (xiii) Precast RC solid planks for roofing/flooring
    - (xiv) Precast RCL panel roofing system
    - (xv) Precast reinforced brick panels for walls and roofing/flooring
    - (xvi) Particle board for door shutters
    - (xvii) Precast RCC frames for doors and windows
    - (xviii) Magnesium oxychloride door frames
    - (xix) Magnesium oxychloride tiles for flooring
    - (xx) Stabilised soil cement base for cement concrete floor
    - (xxi) Partial replacement of cement by flash in mortar and concrete

(xxii) Single stack system of plumbing
(xxiii) Precast thin lintels
(xxiv) Water proofing in roof with lime concrete terracing
(xxv) Tamping machine for tamping lime concrete on roof
(xxvi) Surface water proofing of mud walls
(xxvii) Corrugated roofing sheets from coir waste
(xxviii) Fire retardant treatment of thatch
(xxix) Improved clay roofing tiles
(xxx) Improved design of brick kiln and lime kiln

2. Structural Engineering Research Centre (SERC), Madras:

(i) Hyperbolic paraboloid footings
(ii) Precast RC waffle unit for roofing/flooring
(iii) Prestressed concrete hyperboloid shell
(iv) Precast doubly curved shells for roofing/flooring
(v) Hyperbolic paraboloid shell roof
(vi) Brick shell roof with flat bricks
(vii) Lime-Flyash cellular slab for roofing
(viii) Use of high strength deformed bars and ultimate design procedures
(ix) Use of flyash in mortars and concrete
(x) Use of flyash in precast prestressed concrete products
(xi) Ferro-cement concrete water tank
(xii) Ferro-cement concrete silos, bins, etc., for grain storage
(xiii) Precast slab, using hollow clay blocks for floor roofs system
(xiv) Precast RC joists and hollow clay blocks roofs
(xv) Precast channel units
(xvi) On site large panel prefabrication
(xvii) Precast two-way spanning flooring/roofing scheme
(xviii) Electrothermal prestressing
(xix) Prestressed concrete railway sleepers
(xx) Fibre reinforced concrete manhole covers
(xxi) Prestressed concrete poles
(xxii) Latro blocks (building blocks from latrite soil)

3. National Council for Cement and Building Materials, Delhi:
   - (i) Use of flyash in mortars and plasters
   - (ii) Use of flyash in concrete
   - (iii) Production of ready-mixed concrete
   - (iv) Production of strength mix design of concrete
   - (v) Cement soil stabilised blocks
   - (vi) Precast roofing tiles for low cost housing
   - (vii) Portland pozzolana cement
   - (viii) Prevention of chemical attack on reinforced concrete structures

4. Central Road Research Institute, Delhi:
   - (i) Reactive Surkhi
   - (ii) Waterproof mud plaster on mud walls
   - (iii) Flyash as partial replacement of fine aggregate in cement concrete
   - (iv) Lime/burnt clay pozzolana
   - (v) Direct field adjustment chart for control on concrete quality
   - (vi) Bituminous materials in the water proofing of mud walls

5. Central Electro-Chemical Research Institute, Karaikudi, Tamil Nadu:
   - (i) Prevention of corrosion of reinforcement in brick work
   - (ii) Prevention of corrosion of steel reinforcement cement concrete
   - (iii) Prevention of corrosion of steel
   - (iv) Corrosion in buildings—level of corrosibility in different regions of India

6. Forest Research Institute, Dehradun:
   - (i) Secondary species of timber
   - (ii) Small and medium span nail jointed timber trusses
   - (iii) Utilization of short length small dimension timbers for construction purposes
   - (iv) Termite proofing of building and houses
   - (v) Fire retarding and preservative treatment of thatch roof
   - (vi) Preservative treatment of bamboos

7. Indian Plywood Industries Research Institute, Bangalore:

   (i) Veneers plywood shingles for roofing

   (ii) Exterior grade plywood for roofing and walling

   (iii) Hard-board for exterior applications

   (iv) Glued wood—plywood structural components like beams and structural components

   (v) Glued laminated doors and window frames and other glued laminated products using structural synthetic resin adhesive

8. Regional Research Laboratory, Jorhat:

   (i) Cement bonded fibre roofing sheets

   (ii) Rice-husk flyash pozzolana

   (iii) Paddy husk bricks

   (iv) Paper corrugated roofing sheets

   (v) Flooring tiles for A.C. waste

   (vi) Bamboocrete for wall panel and roof

   (vii) Water filter candle for obtaining drinking water

   (viii) Cheap sanitary septic tanks from waste bitumen drums

9. School of Research & Training in Earthquake Engineering, University of Roorkee:

   (i) Single brick thick load bearing walls for 4 storeyed residential buildings

   (ii) Single brick thick load bearing walls for 5 storeyed residential buildings

   (iii) Half brick thick 'Z' shaped load bearing walls

   (iv) Seismic design of present RC systems for roofing/flooring

10. Hindustan Prefab Ltd., Delhi:

   (i) Partial prefabricated framed structure with RC columns and beams

   (ii) Pocket connections for precast columns with foundation

   (iii) Load bearing concrete panels for walls

   (iv) Hollow cinder block masonry

   (v) Lime and flyash hollow block masonry

   (vi) Precast battens and hollow blocks for roofs and floors

   (vii) Precast RC cored roofing/flooring system

- (viii) Prestressed cement concrete beams
- (ix) Prestressed concrete hollow cored slab resting in prestressed concrete beams for roofing and flooring
- (x) Precast RC single flight staircase monolithically cast with landing
- (xi) Prestressed concrete frames for doors and windows
- (xii) Modified horizontal and vertical joints between concrete wall panels
- (xiii) Full panel prefab method of construction
- (xiv) Channel slab for roofing in residential and industrial buildings

11. Bureau of Indian Standards, Delhi:
    - (i) National Building Code
    - (ii) Standards for low-income group housing
    - (iii) Modular coordination in buildings
    - (iv) Standard building specifications and codes
    - (v) Standard method of measurements
    - (vi) Standard output norms for materials
12. U.P. PWD Research Institute, Lucknow:
    - (i) Strength of brick masonry and mortars
    - (ii) Waterproofing of flat roofs
    - (iii) Replacement of cement by surkhi
    - (iv) Damp proof construction of walls
13. Planning, Research and Action Institute, Lucknow:
    - (i) Investigations of comparative efficiency of different types of chullhas and evolving design of smokeless chullhas
14. Sri Ram Institute of Industrial Research, Delhi:
    - (i) Production of clay pozzolana by fluidized method
    - (ii) Production of gypsum plaster by fluidized method
15. Building & Road Research Laboratory, Chandigarh:
    - (i) Bitumen stabilised soil bricks
16. Central Fuel Research Institute, Dhanbad
    - (i) Flyash bricks

17. Central Mechanical Engineering Research Institute, Durgapur:
    - (i) Development of simple brick making machine
    - (ii) Economized steel structure of open web sections
    - (iii) Design development for castellated beams
18. National Environmental Engg. Research Institute, Nagpur:
    - (i) Sanitary rural latrines
    - (ii) Garbage chutes in multi-storeyed buildings
19. College of Military Engineering (CME), Pune:
    - (i) Precast roofing/flooring units such as cored units, channel units, waffles shells and hyperboloid shells
    - (ii) Damp proof course in cement mortar (1:4) with air entraining agent
20. Regional Engineering College, Warangal:
    - (i) Composite joists filler blocks for roof floors
    - (ii) Ribbed slab floor roof (large units)
    - (iii) Ribbed slab floor roof (small units)
21. Bengal Engineering College, Howrah (West Bengal):
    - (i) Precast RC columns with bracket erected and fixed in recesses of RCC footings laid in situ
    - (ii) Precast and prestressed beams resting on brackets of the columns
    - (iii) Composite precast RC battens and hollow cinder blocks for flooring
    - (iv) Precast and prestressed folded plate roof
    - (v) Hollow cinder blocks masonry
22. Maharashtra Engineering Research Institute, Nasik:
    - (i) Use of surkhi in cement mortar as an inert
    - (ii) Durability of pozzolana mortars and concrete
    - (iii) Unburnt building bricks
23. I.I.T., Madras:
    - (i) RC portal frames construction
    - (ii) Clay products for roofing
    - (iii) Composite slab with RCC joists and brick in fill for floors/roofs

(iv) Hollow grid slabs for roof/floors
(v) Simple hand operated hollow block making machine
(vii) Shell foundation

24. I.I.T., Kanpur:
(i) Cement from rice-husk

25. Neyveli Lignite Corporation, New Delhi:
(i) Flyash lime gypsum brick for masonry

26. National Building Organisation, Delhi:
(i) Modular concept in planning and design of building
(ii) Clay pozzolana for mortars
(iii) Dry-hydrated lime for mortars and concrete
(iv) Cellular concrete building products
(v) High strength bricks and structural clay products
(vi) Asphaltic roofing, sheets
(vii) Ribbed floors/roofs of concrete
(viii) Load bearing 19 cm thick brick walls
(ix) PVC pipes
(x) Plastic stays for steel windows
(xi) Hundson brick making machine
(xii) Sundried bricks and non-erodable water proof mud plaster
(xiii) Fire retardant treatment of thatch
(xiv) Preservative treatment of bamboos
(xv) Reed boards for roof and walling
(xvi) Bamboo reinforced concrete for roofing
(xvii) Lower ceiling height

Machine Tools and Robotics

THE TECHNOLOGICAL revolution taking place in the area of machine tools, inspection devices and handling equipment is now poised to bring rich dividends both in productivity and quality, the two factors required for success in an increasingly competitive market.

The new revolution has been triggered off by electronics and sustained by ever increasing capabilities of computers. This has led to emergence of a new technology called 'Mechtronics' symbolising the synthesis of mechanical aspects. The heart of mechtronics revolution, Computer Numerical Control, more popularly known as CNC technology, made a slow start in the 1960s in the world, its phenomenal growth was witnessed only in 1970s and 1980s by virtue of its contribution towards higher productivity and substantial cost reduction.

In India, the first step before initiating in-house R&D was to assimilate technology imported from abroad. In the context of metal working, the technology which Indian machine tool builders imported during the 1950s and 1960s, provided the initial bulk to assimilate and start in-house R&D towards the advanced development of the products or to attempt the design and development of absolutely new products and processes. Organised production of standard machine tools commenced in the 1950s in collaboration with renowned foreign machine tool builders. In a bid to get the best in the world, collaborating firms from West Germany, Switzerland, UK, USA, France and Italy were selected to produce many general purpose machine tools under licence. By and large, even during sixties, much of what the Indian machine tool industry produced was based on imported know-how. But right in the early years of that decade some machine tool manufacturers started their own design and development sections because they were aware of the pitfalls of permanently depending on foreign source for the know-how to design, develop and produce machine tools. Around the same time, the Central Machine Tools Institute was set up in Bangalore to help the Indian machine tool industry in the field of R&D.

In the beginning, the Indian designers faced many hurdles, and progress was slow. The first indigenously designed centre lathe of this period and an electrically controlled milling machine took a long lead time to bring them to the level of production. But the important thing was that a beginning had been made, and the pride of achievement spurred the Indian designers to attempt more. This led to the indigenous design and development of a number of machine tools during the 1970s. It was at this time that many other manufacturers in the medium sector also started bestowing attention on productionizing their own designs, or those obtained from the Central Machine Tool Institute in Bangalore.

Even as the Indian R&D engineers were striving hard to master the techniques of designing general purpose machine tools during the sixties, the developments abroad were aimed at exploring new frontiers. The advent of numerical control or NC, which was first tried on aircraft profilers in USA, had spread to a number of other applications like turning, milling and drilling. A new breed of machine tools like NC lathes, NC toolroom milling machines and NC machining centres made their debut, promising levels of productivity that were just inconceivable with general purpose machine tools. The advent of NC threw the manufacturing scene into a ferment. The astounding pace of developments in electronic hardware and software made the NC machine tools valuable production aids. Automation was pushed to higher levels achieve unfailing accuracy and higher productivity. Computer techniques led to computer-aided design (CAD) and computer-aided manufacturing (CAM). Robots were developed to relieve man from working in hazardous environments. Robots were integrated into the manufacturing chain to facilitate continuous production, boosting productivity to very high levels. In fact, the philosophy of development was to achieve higher productivity R&D in machine tools involved a multi-disciplinary approach a blend of mechanics and electronics. The essence of development was the shift from single purpose machine tools to combining several operations in one machine by providing the tools, changing them automatically and even automating job loading and unloading. Add to this the features of self-monitoring, diagnostics and fault correction, the end result is the advanced machine tool of today. This is the picture of developments from 1970 onwards.

Indian R&D engineers continued the task of designing and developing more advanced general purpose machine tools like copying lathes, precision, grinding machines, special purpose machines and gear cutting machines during the decade of 1970s. They did not remain indifferent to technological developments taking place abroad. In 1973 the first NC lathe was built in India, and this was followed by the first Turret Machining Centre in 1974. These machines were, however, interfaced with imported

NC controls. By 1979 the technological strength of Indian R&D engineers was even more evident when they exhibited the first slant bed NC lathe and vertical machining centre in the IMTEX exhibitions. By 1982, development efforts had touched even sophisticated CNC machining centre with auto-tool changer. Turning centres and CNC vertical turning centres, all incorporating advanced features. But the country still relied heavily on imported controls. A beginning has now been made to built systems indigenously.

Although CNC technology was firmly established in advanced countries by mid-70s, its development and application in India was rather tardy. The global view of technological developments in machine tools is replete with the sophistication of CNC machines such as CNC turning centres, CNC grinding centres, gear making machines and CNC electro discharge machines. These CNC machines are the building block of future manufacturing systems. Flexibility in production is now sought to be introduced by linking these CNC machines with automatic work and tool handling systems such as robots and robotrailers, automatic inspection systems and fault diagnosis systems.

In India, the first CNC machine was introduced in the machine tools industry almost a decade ago. In the field two institutions have assumed a pioneering role. They are the Central Machine Tools Institute (CMTI) on research and design side, and the public-sector Hindustan Machine Tools (HMT) on manufacturing side. Both these institutions located in Bangalore have been contributing to the growth of Indian machine tools industry and introduction of latest technology in the field. The present range of indigenous CNC machines include turning centres, and grinding centres. Many other machines such as CNC gear cutting machine, CNC wire out EDM machines and CNC turrent punch presses are under various stages of development.

A number of machine tools including numerical controlled (NC) systems and machines along with necessary hardware and software, accessories, cutting tools and productivity aids have been designed and developed. Many of these machines are under regular production under licence from the institute. The NC division of CMTI has played a key role in introduction of NC machines in the country and is running an intensive development programme in introduction of CNC systems.

The institute is acting as a prime R&D organisation providing technical assistance to the machine tool and engineering industry in the areas of design development, research, manufacturing technology, numerical control, computer aids, testing standards, training and technical information. It has recently developed a decladding machine for profile machining of three dimensional curved surfaces to be used in atomic reactors. Horizontal band saw machine, profile dressing attachment, hydraulic copying equipment for machining cams for earth moving equipment and boring and facing head are some of the other design projects which the institute had completed recently.

The machine tools now under development of CMTI include a precision tool milling machine, a precision lathe, and a CNC cylindrical grinder. The institute has also successfully carried out an interesting project on image processing for object identification using a television camera. This experiment has potential application for development of robotics. The institute is also working on development of a robot for industrial applications.

During the past five years, at least three organisations have initiated development of CNC technology within the country. The CNC systems have been interfaced with machine tools built by leading machine builders. Thus the technological base for CNC systems is now available in the country. But the commercial production capability for CNC machines is yet to be established fully. With an anticipated requirement of about 100 systems per year, the Indian industry needs to make more determined efforts to build indigenously the CNC systems. Since CNC systems constitute a rapidly advanced high technology product the base of development has to be speeded up.

As a result of research and development efforts of CMTI and HMT, the Indian machine tool industry has a reasonably strong technological base. Numerically controlled machines were developed in the country as back as in 1972, and the basic features and specification of the indigenously developed CNC machines since then have been competitive compared to their foreign counterparts. But the emerging market of CNC machines in the country demands more sophistication in operation, controls, precision and flexibility.

Besides CNC machines, another equally exciting development has been the appearance of robots on the metal working scene in a big way during the past five years. Robots have been seen as an answer to the productivity challenge in metal working operations and are already in use on the shop floor for machine tending (component loading and unloading). This trend would further strengthen with coming of unmanned systems and Flexible Manufacturing Systems (FMS), where efficiency of component loading and unloading would be an important criterion. The current trend in robots has been so strong that these developments might become practicable much earlier than expected.

In India, a few research groups have been working on development of robots, but a breakthrough is yet to be made in the field of robots for large scale industrial application. The groups working on robotics include R&D of HMT, CMTI, the Indian Institute of Technology (IIT), Madras, Indian Institute of Science (IIS), Bangalore, and the Hyderabad Science Society, Hyderabad. A few of the engineering colleges have also been working on development of robot arms and sensors.

The public sector defence production unit, Bharat Electronics Limited (BEL), was the first Indian industry to introduce an indigenously developed robot in its production line. It introduced a "pick and place" type robot with a three axis movement in its second television tube production plant at Bangalore. The pneumatically operated robot was incorporated to improve the productivity while maintaining quality in the semi-automated plant, eliminating operator fatigue and other health hazards. Controlled by a microprocessor the robot collects coated TV bulbs from two continuously rotating screen coating equipment and unload them on to an indexing type twelve-headed drying machine. It is also capable of correcting any possible errors due to difference in speeds of the two coating equipment to get overall synchronised movements between the three machines. The display board on the control panel indicates the exact functional area where the fault has occurred to facilitate instant trouble shooting.

The robot control release of coated bulbs from vacuum chucks of the coating machines rotates the lower arms to predetermined positions, centres the neck of the TV bulb on drying equipment. The presence or absence of a bulb in any of the 12 positions is sensed by light modulated photo sensors, which act positively, irrespective of the intensity of the ambient light. Magnetic sensors sense the desired positions of various electro-pneumatic end-effectors. Provisions have also been made in the central control unit of the robot to add more functions down the line if required. Microprocessor controlled scanners scan temperatures in various zones of the screen back and the in-line exhaust system and flash back temperature indications.

The Hyderabad Science Society, which has done pioneering work in the field of robotics, developed the country's first robot few years back. It has also developed a robot with the ability to move about using ultrasonic sensors just like a bat. The ultrasonic sensor developed by the society team, has been attached to Walrobo-two, a robot developed by the society earlier. The robot with ultrasonic sensors could be used in industries involving health hazards such as spraying, chemical and nuclear plants. Tactile sensors to help robots pick up objects and infrared sensors for sensing profile have also been developed. All these extra facilities will be incorporated finally into robotic manipulator.

The robotics laboratory at the school of automation of the Indian Institute of Science (IIS), Bangalore, has developed a microprocessor-based robotic arm. The arm has four joints, each of which is actuated by a stepper motor. The robotic arm can be controlled manually from a front panel or automatically through a video terminal and a key board. The microprocessor has been programmed in such a way that a lay man can control the robotic arm. It can be commanded to pick an object from a specified location or to search, locate and then grip an object within the work area.

All these developments in the newer and exciting areas of CNC machines and robotics are likely to take concrete shape in future and might help in increasing productivity and safety in various industries in the country.

An exercise in technology forecasting conducted in India with special reference to the machine tool industry brought out scenarios and projected the gaps to be bridged. A recent exercise in perspective planning has resulted in a number of recommendations to improve R&D base to make the machine tool industry self-reliant by the end of this decade.

Given the will to pursue R&D work in the spheres in which we are lacking, it will certainly make the industry self-reliant. A healthy and self-supporting machine tool industry will make the metal-working industry and other user industries, like automobile, machine-building, electrical and other engineering industries, more dynamic leading to a tremendous industrial resurgence. That happened in USA, West Germany and Japan and can happen in India also, given the national commitment to foster R&D in all areas of vital importance.

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Appendix A

SCIENTIFIC ORGANISATIONS IN INDIA

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

1. Central Building Research
Institute,
Roorkee-247667.

2. Central Drug Research
Institute,
Chattar Manzil Palace,
Post Box No. 173,
Lucknow-226001.

3. Central Electrochemical
Research Institute,
CECRI Nagar,
Karaikudi-623006.

4. Central Electronics Engineering
Research Institute,
Pilani-333031.

5. Central Food Technological
Research Institute
Mysore-570013.

6. Central Fuel Research Institute,
P.O. FRI,
Dhanbad-828108.

7. Central Glass and Ceramic
Research Institute,
P.O. Jadavpur University,
Calcutta-700032.

8. Central Institute of Medicinal
& Aromatic Plants,
Post Bag No. 1,
P.O. Ram Sagar Misra Nagar,
Lucknow-226016.

9. Central Leather Research
Institute,
Adyar,
Madras-600020.

10. Central Mechanical Engineering
Research Institute,
Mahatma Gandhi Avenue,
Durgapur-713209.

11. Central Mining Research Station,
Barwa Road,
Dhanbad-826001.

12. Central Road Research Institute,
P.O. CRRI,
New Delhi-110020.

13. Central Salt and Marine
Chemicals Research Institute,
Gijubhai Badeka Marg,
Bhavnagar-364002.

14. Central Scientific Instruments
Organisation,
Sector 30,
Chandigarh-160020.

15. Centre for Cellular and
Molecular Biology,
Regional Research Laboratory
Campus,
Uppal Road,
Hyderabad-500007.

16. CSIR Centre for Biochemicals,
VP Chest Institute Building,
University Campus,
Delhi-110007.

17. CSIR Complex Cochin,
Industrial Estate,
P.O. Pappanamcode,
Trivandrum-695018.

18. CSIR Madras Complex,
Taramani, TTTI Post Office,
Madras-600113.

19. Electrical Research and
Development Association,
P.B. No. 760, Makarpura,
Industrial Estate,
P.O. Vadodara-390010.

20. Indian Institute of Chemical
Biology,
4, Raja S.C. Mullick Road,
Jadavpur,
Calcutta-700032.

21. Indian Institute of Petroleum,
P.O. I.I.P.,
Dehradun-248005.

22. Indian National Scientific
Documentation Centre,
14, Satsang Vihar Marg,
Special Institutional Area,
New Delhi-110067.

23. Institute of Microbial
Technology,
House No. 1383, Sector 33 C,
Chandigarh-160031.

24. Industrial Toxicology
Research Centre,
P.O. No. 80,
Mahatma Gandhi Marg,
Lucknow-226001.

25. National Aeronautical
Laboratory,
Post Bag No. 1779,
Bangalore-560017.

26. National Botanical Research
Institute,
Rana Pratap Marg,
Lucknow-226001.

27. National Chemical Laboratory,
Pune-411008.

28. National Environmental
Engineering Research Institute,
Nehru Marg,
Nagpur-440020.

29. National Geophysical
Research Institute,
Uppal Road,
Hyderabad-500007.

30. National Institute of Oceanography,
Dona Paula-403004.
Goa.

31. National Institute of Science,
Technology and Development
Studies,
Hillside Road,
New Delhi-110012.

32. National Metallurgical
Laboratory,
P.O. Burmamines
Jamshedpur-831007.

33. National Physical Laboratory,
Hillside Road,
New Delhi-110012.

34. Publications and Information
Directorate,
Hillside Road,
New Delhi-110012.

35. Regional Research Laboratory,
Library Building (Ground Floor),
University of Bhopal,
Bhopal-462026.

36. Regional Research Laboratory,
Bhubaneswar-751013.

37. Regional Research Laboratory,
Uppal Road,
Hyderabad-500007.

38. Regional Research Laboratory,
Canal Road,
Jammu-Tawi-180001.

39. Regional Research Laboratory,
Jorhat-785006 (Assam).

40. Regional Research Laboratory,
Industrial Estate,
P.O. Pappanamcode,
Trivandrum-695019.

41. Structural Engineering Research Centre,
CSIR Complex,
TTTI-Taramani (Post)
Madras-600113.

42. Structural Engineering Research Centre,
Roorkee-247672.

43. Tocklai Experimental Station,
Tea Research Association,
Jorhat-785008 (Assam).

44. CSIR Complex
Palampur (H.P.)

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

1. All India Coordinated Rice
Improvement Project,
Rajendra Nagar,
Hyderabad-500030.

2. All India Coordinated
Research Project on Dryland
Agriculture,
2-2-58/60, Amberpet,
Hyderabad-500013.

3. Central Agricultural
Research Institute
for Andaman & Nicobar
group of Islands,
Port Blair-744101.

4. Central Avian Research
Institute,
Izatnagar-243122.

5. Central Arid Zone Research
Institute,
Jodhpur-342001.

6. Central Inland Fisheries
Research Institute,
Barrackpore-743101.

7. Central Institute of Agriculture,
Shri Guru Teg Bahadur Complex,
Addl. 'A' Block, New Market,
T.T. Nagar, Bhopal-462003.

8. Central Institute for Cotton
Research,
95, Pushpa Kunj,
Canal Road,
New Ramdaspeth,
Nagpur-440010.

9. Central Institute of Fisheries
Education,
Post Box No. 7392,
Kakori Camp, Jaiprakash Road,
Bombay-400061.

10. Central Institute of Fisheries
Technology,
P.O. Mastsyapuri,
Cochin-682029.

11. Central Marine Fisheries
Research Institute,
P.O. No. 1912,
Cochin-682018.

12. Central Plantation Crops
Research Institute,
Post Kudlu,
Kasargod-675017.

13. Central Rice Research
Institute,
Simla-171001.

14. Central Rice Research
Institute,
Cuttack-753006.

15. Central Sheep & Wool Research
Institute,
P.O. Avikanagar-304501, (Via, Jaipur).

16. Central Soil Salinity Research
Institute,
Karnal-132001.

17. Central Soil & Water
Conservation Research &
Training Institute,
218, Kaulagarh Road,
Dehradun-248195.

18. Central Tobacco Research
Institute,
Rajahmundry-533104.

19. Central Tuber Crops Research
Institute,
Sreekariyam,
Trivandrum-695017.

20. Cotton Technological Research
Laboratory,
Adenwala Road,
Matunga,
Bombay-400019.

21. Directorate of Oilseeds
Research, 'D' Block,
College of Agriculture,
Rajendranagar,
Hyderabad-500030.

22. Indian Agricultural Research
Institute,
Hillside Road, Pusa,
New Delhi-110012.

23. Indian Agricultural Statistics
Research Institute,
Library Avenue,
New Delhi-110012.

24. ICAR Research Complex
for North Eastern
Hills Region,
Cadar Lodge, Jawai Road,
Shillong-793003.

25. Indian Grassland & Fodder
Research Institute,
Gwalior Jhansi Road,
Jhansi-234001.

26. Indian Institute of
Horticultural Research,
255, Upper Palace Orchards,
Bangalore-560080.

27. Indian Institute of
Sugarcane Research,
Post Office Dilkhusha,
Lucknow-226002.

28. Indian Lac Research Institute,
P.O. Namkum,
Ranchi-83401

29. Indian Veterinary Research
Institute,
Izatnagar-243122.

30. Jute Agricultural Research
Institute,
24-Paraganas, P.O.
Barrackpore-743101.

31. Jute Technological Research
Laboratory,
12, Regent Park,
Calcutta-700040.

32. National Academy for
Agricultural Research
Management,
Rajendranagar,
Hyderabad-500030.

33. National Bureau of Plant
Genetic Research,
F.C.I. Building,
C.T.O. Complex,
Pusa,
New Delhi-110012.

34. National Bureau of Soil
Survey and Land Use
Planning,
Seminary Hills,
Nagpur-440006.

35. National Dairy Research
Institute,
Karnal-132001.

36. National Goat Research
Institute,
Makhdoom, P.O., Farah,
District, Mathura-281122.

37. National Research Centre
for Groundnut,
Maharashi Dayanand Farm,
Gujarat Agricultural University
Campus, Junagarh.

38. Sugarcane Breeding Institute,
Lawley Road,
Coimbatore-641007.

39. Vivekananda Parvitya Krishi
Anusandhan Shala,
Almora-263601.

INDIAN COUNCIL OF MEDICAL RESEARCH

Permanent Institutes/Centres

1. National Institute
of Nutrition,
Jamai-Osmania,
Hyderabad-500007.

2 National Institute of
Virology,
20-A, Dr. Ambedkar Road,
Pune-411001.

3. Institute of Research
in Reproduction,
Jehangir Merwanji Street,
Parel,
Bombay-400012.

4. Tuberculosis Research Centre,
Spur Tank Road,
Chetput,
Madras-600031.

5. Institute of Immunohematology
(Formerly Blood Group
Reference Centre),
Seth G.S. Medical College,
Parel,
Bombay-400012.

6. National Institute of Cholera
and Enteric Diseases,
3, Dr. M. Ishaque Road,
(Kyd Street),
Calcutta-700016.

7. Institute of Pathology,
Safdarjang Hospital,
New Delhi-110029.

8. National Institute of
Occupational Health,
Meghani Nagar,
Ahmedabad-380016.

9. Vector Control Research Centre,
Indira Nagar,
Gorimedu,
Pondicherry-605006.

10. Laboratory Animal Information
Service,
National Institute of
Nutrition,
Jamai-Osmania,
Hyderabad-500007.

11. Food and Drug Toxicology
Research Centre,
National Institute of
Nutrition,
Jamai-Osmania,
Hyderabad-500007.

12. Central Jalma Institute
for Leprosy,
Tajganj,
Agra-282001.

13. Malaria Research Centre,
22, Sham Nath Marg,
Delhi-110054.

14. Institute for Research
& Medical Statistics,
ICMR Campus,
Ansari Nagar,
New Delhi-110029.

15. Institute for Research
in Medical Statistics,
Sathyamurthi Road, Chetput,
Madras-600031.

16. Cytology Research Centre,
Maulana Azad Medical College,
New Delhi-110012.

17. Enterovirus Research Centre,
Haffkine Institute,
Parel, Bombay-400012.

18. Rajendra Memorial Research
Institute for Medical
Sciences,
Agam Kuan,
Patna-800007.

Centres for Advanced Research

1. Centre for Advanced Research
in Reproductive Biology,
Indian Institute of Science,
Bangalore-560012.

2. Centre for Advanced Research
in Genetics and Cell Biology,
Indian Institute of Science,
Bangalore-560012.

3. Centre for Advanced Research
in Neuropharmacology,
K.G. Medical College,
Lucknow-226003.

4. Centre for Advanced Research
in Virology,
Christian Medical College,
Vellore-632004.

5. Centre for Advanced Research
in Community Psychiatry.
National Institute of Mental
Health and Neurosciences,
Bangalore-560029.

6. Centre for Advanced Research
in Haematology
Postgraduate Institute of
Medical Education
and Research,
Chandigarh-160012.

7. Centre for Advanced Research
in Neurobiochemistry,
Osmania Medical College,
Hyderabad-500007.

Regional Medical Research Centres

1. Regional Medical Research
Centre,
Belgaum.

2. Regional Medical Research
Centre,
Bhubaneswar.

3. Regional Medical Research
Centre,
Dibrugarh.

4. Regional Medical Research
Centre,
Jabalpur.

5. Regional Medical Research
Centre,
Jaipur.

6. Regional Medical Research
Centre,
Port Blair.

DEFENCE RESEARCH & DEVELOPMENT ORGANISATION

1. Armament Research & Development
Establishment,
Pashan,
Pune-411021.

2. Explosives Research &
Development Laboratory,
Pashan,
Pune-411021.

3. Instruments Research &
Development Establishment,
Raipur,
Dehradun-248008.

4. Terminal Ballistics Research
Laboratory,
Sector 30,
Chandigarh-160020.

5. Proof & Experimental
Establishment,
Balasore-756001.

6. Defence Research & Development
Laboraotry,
Phisalbanda, P.O. DMRL,
Hyderabad-500258.

7. Electronics & Radar Development
Establishment,
P.O. Box No. 5108,
High Grounds,
Bangalore-560001.

8. Solid State Physics Laboratory,
Lucknow Road,
Timarpur,
Delhi-110007.

9. Defence Electronics Research
Laboratory,
Chandrayanagutta Lines,
Hyderabad-500005.

10. Defence Electronics
Applications Laboratory,
Sunder Wala Camp,
P.O. Raipur,
Dehradun-248008.

11. Research & Development
Establishment,
(Engineers) Pioneer Lines-Dighi
Pune-411015.

12. Snow & Avalanche Study
Establishment,
C/o 56 APO.

13. Defence Institute of
Fire Research,
Probyn Road,
Delhi-110007.

14. Combat Vehicles Research &
Development Establishment
Avadi
Madras-600054.

15. Vehicles Research &
Development Establishment
Ahmednagar-414001.

16. Aeronautical Development
Establishment,
Jeewan Bhimanagar,
Bangalore-560075.

17. Gas Turbine Research
Establishment,
Suranjan Das Road,
P.B. No. 1777,
Bangalore-560075.

18. Centre for Aeronautical
Systems Studies and Analysis
263, Mahalakshmi Layout,
Bangalore-560010.

19. Defence Bio-Engineering and
Electro Medical Laboratory
Indira Nagar,
Bangalore-560038.

20. Naval Chemical &
Metallurgical Laboratory,
Naval Dockyard,
Bombay-400001.

21. Naval Physical & Oceanographic
Laboratory,
Naval Base,
Cochin-682002.

22. Naval Science & Technological
Laboratory,
Visakhapatnam.

23. Defence Science Centre,
Metcalfe House,
Delhi-110054.

24. Defence Materials &
Stores Research &
Development Establishment,
P.B. No. 320,
Kanpur-208004.

25. Defence Metallurgical
Research Laboratory,
P.O. DMRL,
Hyderabad-500258.

26. Defence Laboratory,
Post Box No. 136,
Jodhpur.

27. Aerial Delivery Research
& Development Establishment
P.B. No. 51,
Station Road,
Agra Cantt.

28. Defence Research &
Development Establishment,
Tansen Road,
Gwalior-474002.

29. Defence Food Research
Laboratory,
Jyothi Nagar,
Mysore-570010

30. Defence Research Laboratory,
Post Box No. 2
Tezpur (Assam)-784001.

31. Field Research Laboratory,
C/o 56 APO.

32. Defence Scientific Information
and Documentation Centre,
Metcalfe House,
Delhi-110054.

33. Institute of Nuclear Medicine
and Allied Sciences,
Probyn Road,
Delhi-110007.

34. Defence Institute of Physiology and
Allied Sciences
Delhi Cantt—110010.

35. Agricultural Research Unit,
Almora.

36. Defence Research &
Development Unit,
S-2/2 Commissariate Road,
Hastings,
Calcutta-700022.

37. Institute of Armament
Technology,
Singabad Road,
Girinagar,
Pune-411025.

38. Defence Institute of
Work Study,
Landour Cantt,
Mussoorie-248179.

39. Institute for Systems
Studies & Analysis,
(ISSA), Metcalfe House,
Delhi-110054.

40. Defence Terrain Research
Laboratory,
Metcalfe House,
Delhi-110054.

41. Directorate of Psychological
Research,
West Block No. 8, Wing No. 1,
R.K. Puram,
New Delhi-110022.

DEPARTMENT OF ATOMIC ENERGY

R & D Units

1. Bhabha Atomic Research Centre
Chhatrapati Shivaji Marg,
Bombay-400085.

2. Reactor Research Centre
Kalpakkam,
Tamil Nadu.

3. Gauribidanur Seismic Station
Bangalore.

4. High Altitude Research
Laboratory
Gulmarg,
Jammu & Kashmir.

5. Nuclear Research Laboratory
Srinagar.

6. Variable Energy Cyclotron
Centre
Bidhan Nagar,
Calcutta-700064.

Power Sector

1. Atomic Minerals Division
1-11-1200 Begumpet
Hyderabad-500016.

2. Nuclear Fuel Complex,
ECIL Post
Hyderabad-500762.

3. Nangal Heavy Water Plant
Nangal,
Punjab.

4. Baroda Heavy Water Plant
Baroda. Gujarat.

5. Kota Heavy Water Plant
Kota, Rajasthan.

6. Tuticorin Heavy Water Plant
Tuticorin,
Tamil Nadu.

7. Talcher Heavy Water Plant
Talcher,
Orissa.

8. Thal-Vaishet Heavy Water Plant
Maharashtra.

9. Manuguru Heavy Water Plant
Vijayawada,
Andhra Pradesh.

10. Power Projects Engineering Division
Colaba,
Bombay-400005.

11. Tarapur Atomic Power Station,
Tarapur,
Bombay.

12. Rajasthan Atomic Power Station,
Kota,
Rajasthan.

13. Madras Atomic Power Project
Kalpakkam, Tamil Nadu.

14. Narora Atomic Power Project
Narora, U.P.

15. Kakrapara Atomic Power Project
Kakrapara, Gujarat.

Industrial Units

1. Indian Rare Earths Ltd.
Alwaye, Kerala.

2. Electronics Corporation of
India Ltd.
Cherlapalli,
Hyderabad-500040.

3. Uranium Corporation of
India Ltd.
Jadiguda Mines,
Singhbhum-832102.

Aided Institutions

1. Tata Institute of
Fundamental Research
Homi Bhabha Road
Colaba,
Bombay-400005.

2. Tata Memorial Centre
De Earnest Borges Marg
Parel,
Bombay-400012.

3. Saha Institute of
Nuclear Physics
Block-AF, Sector 1, Bidhan Nagar,
Calcutta-700064.

DEPARTMENT OF ELECTRONICS

Departmental Centre

1. National Informatics Centre
CGO Complex
New Delhi-110001

Public Sector Undertakings

1. Electronic Trade and Technology
Development Corporation (ETTDC),
15/49 Malcha Marg,
New Delhi-110021.

2. Computer Maintenance
Corporation (CMC)
8th Floor, Air India Building,
Nariman Point,
Bombay-400001.

3. Semiconductor Complex Ltd.
Chandigarh.

DEPARTMENT OF ENVIRONMENT

1. Zoological Survey of India
34, Chittranjan Avenue,
Calcutta-700012.

2. Botanical Survey of India
Post Office, Botany Gardens,
Shibpur,
Howrah-700003.

3. National Museum of Natural History
Barakhamba Road,
New Delhi-110001.

4. Central Board of Preventive and
Control of Water Pollution
6th Floor, Skylark Building,
60 Nehru Place,
New Delhi-110019.

DEPARTMENT OF SCIENCE & TECHNOLOGY

Research Organisations/Institutions

1. Birbal Sahni Institute
of Palaeobotany
53, University Road,
Lucknow-226007.

2. Bose Institute
93/1, Acharya Prafulla
Chandra Road
Calcutta-700009.

3. National Institute of
Immunology
Jawaharlal Nehru University
Campus,
New Delhi-110029.

4. Raman Research Institute
Hebal P.O.
Bangalore-560006.

5. Sree Chitra Tirunel Medical
Institute for Science and
Technology,
Trivandrum.

6. Wadia Institute of Himalayan
Geology,
13, Municipal Road,
Dehradun-248001.

7. National Atlas and Thematic
Mapping Organisation,
50-A, Garihat Road,
Calcutta-700019.

Survey

8. Survey of India
Block No. 8,
Hathibarkala Estate
Dehradun-248001.

Park

9. Padmaja Naidu Himalayan
Zoology Park
Jawahar Park, Jawahar Parbat,
Darjeeling.

Academy/Association/Society

10. Indian National Science
Academy
Bahadur Shah Zafar Marg,
New Delhi-110002.

11. Indian Science Congress
Association
Dr. Bireshuha Street,
Calcutta-700017.

12. Indian Association for the
Cultivation of Science,
Jadavpur,
Calcutta-700032.

13. Maharashtra Association for
the Cultivation of Science,
Law College Road,
Poona-411004.

14. Bombay Natural History Society
Hornbil House
Shahid Bhagat Singh Road
Bombay-400023.

15. Indian Academy of Sciences
Bangalore.

Public Sector Corporation

16. Central Electronics Ltd.,
Industrial Area 4,
Sahibabad-201005.

17. National Research Development
Corporation,
20-22, Jamroodpur Community
Centre,
Kailash Colony Extension,
New Delhi-110048.

DEPARTMENT OF SPACE

1. INSAT-I Space Segment
Project Office,
Chandra Kiran Building;
Kasturba Road,
Bangalore-560001.

2. National Remote Sensing Agency,
No. 4. Sardar Patel Road,
Secunderabad-500003.

3. Physical Research Laboratory,
Navrangapura,
Ahmedabad-380009.

4. Indian Space Research
Organisation,
Headquarters,
Cauvery Bhavan,
Kampegowda Road,
Bangalore-560009.

5. ISRO Satellite Centre,
A-16, Peenya Industrial Estate,
Bangalore-560058.

6. Space Applications Centre,
Jodhpur, Tekhra,
Ahemedabad-380053.

7. SHAR Centre,
Sriharikota,Sullurupeta,
Nellore Dist-524124.

8. Vikram Sarabhai Space Centre,
Trivandrum-695002.

9. Auxiliary Propulsion System
Unit
Bangalore.

DEPARTMENT OF BIOTECHNOLOGY

1. National Institute of Immunology,
New Delhi.

2. International Centre for Genetic
Engineering and Biotechnology,
New Delhi.

DEPARTMENT OF OCEANOGRAPHY

Agencies involved in Oceanography Research:

1. National Institute of Oceanography, Goa.
2. Central Marine Fisheries Research Institute, Cochin.
3. Geological Survey of India.
4. Indian Meteorological Department, New Delhi.
5. Oil & Natural Gas Commission, Dehradun.
6. Department of Fisheries, New Delhi.
7. Department of Environment, New Delhi.
8. Naval Hydrographic Office.
9. Central Electricity Authority, New Delhi.
10. Centre for Earth Sciences Studies, Trivandrum.
11. National Geophysical Research Institute, Hyderabad.
12. Physical Research Laboratory, Ahmedabad.
13. Naval Physical and Oceanographic Laboratory.
14. Institute of Tropical Meteorology, Pune.
15. Indian Institutes of Technology.
16. Central Salt and Marine Chemical Research Institute, Bhavnagar.
17. Bharat Heavy Electricals Limited.
18. Engineers India Limited.
19. Regional Research Laboratory, Bhubaneswar.
20. National Meteorological Laboratory, Jamshedpur.
21. Hindustan Zinc Limited, Udaipur.
22. Hindustan Copper Limited, Khetri and Ghatsila.
23. Indian School of Mines, Dhanbad.
24. Jadavpur University, Calcutta.
25. National Remote Sensing Agency, Hyderabad.
26. Centre for Cellular & Molecular Biology, Hyderabad.
27. Indian Institute of Geomagnetism, Bombay.
28. Sriram Institute of Industrial Research, Delhi.
29. Punjab Wireless Systems Limited, Chandigarh.
30. Three Defence Services, namely, Army, Navy and Air Force.
31. Department of Non-Conventional Energy Souces.

MINISTRY OF AGRICULTURE

Attached Offices

1. Agricultural Prices Commission,
Krishi Bhawan,
New Delhi-110001

2. Directorate of Economics and
Statistics,
Krishi Bhawan,
New Delhi-110001

3. Directorate of Plant
Protection, Quarantine
and Storage,
NH-IV, Faridabad,
Haryana.

Subordinate Offices

1. Directorate of Extension,
Sector-1. R.K. Puram,
New Delhi-110022

2. Directorate of Sugarcane
Development,
No.1, Shyam Enclave,
Giani Border,
Sahibabad, Ghaziabad,
Uttar Pradesh.

3. Directorate of Jute
Development,
234/4, Acharya Jagdish
Bose Road,
Nizam Place,
Calcutta-700020.

4. Directorate of Tobacco
Development,
27, Eldamas Road, Teynampet,
Madras-600018.

5. Directorate of Oilseeds
Development,
Telhan Bhavan,
Himayatnagar,
Hyderabad-500029.

6. Directorate of Rice
Development,
241, Patliputra Colony,
Patna-800013.

7. Directorate of Millets
Development,
19, Krishnamachari Road,
Madras-600034.

8. Directorate of Cotton
Development,
14, Ramjibhai Kamani Marg,
Ballard Estate, P.B. No. 1002
Bombay-400038.

9. Directorate of Pulses
Development,
B-2, Sector C, Aliganj Scheme,
Lucknow-226006.

10. Directorate of Coconut
Development,
P.B. No. 1027, Ernakulam,
Cochin-682011.

11. Directorate of Cocoa,
Arecanut and Spices
Development,
P.B. No. 14, 1/500,
Cannanore Road,
Calicut-673006.

12. Directorate of Cashewnut
Development,
M.G. Road,
Cochin-682011.

13. Office of Minister
(Agriculture),
Embassy of India
Rome, Italy.

14. Forest Survey of India,
25, Subhash Road,
Old Forest Rangers College,
Dehradun.

15. Logging Development Institute,
25, Subhash Road,
Old Forest Rangers Road,
Dehradun.

16. Forest Research Institute
& Colleges,
P.O. New Forest,
Dehradun.

17. Directorate of Lac Development,
Circular Road,
Ranchi, Bihar.

18. Directorate of Agriculture
Aviation,
Safdarjung Airport,
New Delhi-110003

19. Central Fertiliser
Control Laboratory,
NH-IV, Faridabad, Haryana,

20. Tractor Training &
Testing Station,
Tractor Nagar,
Budhi, M.P.

21. Tractor Training Centre,
Tractor Nagar,
Hissar, Haryana.

22. Delhi Milk Scheme,
West Patel Nagar,
New Delhi-110008.

23. Central Cattle Breeding Farm,
Dhamrod, P.O. Dhamrod,
Distt. Surat, Gujarat.

24. Central Cattle Breeding Farm,
Andeshnagar,
Distt, Lakhimpur U.P.

25. Central Cattle Breeding Farm,
Suratgarh, Rajasthan.

26. Central Cattle Breeding Farm,
Similiguda, P.O. Sunabeda,
Koraput, Orissa.

27. Central Cattle Breeding Farm,
Chiplima, P.O. Kalamati,
Distt. Sambalpur,
Orissa.

28. Central Cattle Breeding Farm,
P.O. Avadhi, Alamadhi,
Madras-600052.

29. Central Cattle Breeding Farm,
Hesserghatta,
Bangalore North.

30. Central Frozen Semen Production
& Training Institute,
Hesserghatta,
Bangalore North.

31. Central Herd Registration Unit,
10, Gautam Vihar Cooperative
Society Building,
Usmanpura,
Ahmedabad-13.

32. Central Herd Registration Unit,
W-15, Jagdish Colony,
Rohtak, Haryana.

33. Central Herd Registration Unit,
34, G.N.M. Colony,
Christianganj,
Ajmer,
Rajasthan-305001.

34. Central Herd Registration Unit,
Santhapet,
Ongole-523001.

35. Regional Station on Forage
Production and Demonstration,
P.O. Netaji Subhash Sanitorium,
Kalyani, Distt. Nadia,
West Bengal.

36. Regional Station on Forage
Production and Demonstration,
48, Rajbagh (Extension),
Srinagar, J&K

37. Regional Station on Forage
Production and Demonstration,
Suratgarh, Rajasthan.

38. Regional Station on Forage
Production and Demonstration,
P.O. Textile Mill,
Hissar, Haryana.

39. Regional Station on Forage
Production and Demonstration,
GA 128/2 Sector No. 30,
Gandhi Nagar,
Gujarat.

40. Regional Station of Forage
Production and Demonstration,
Avadhi, Alamadhi,
Madras-600052.

41. Regional Station on Forage
Production and Demonstration,
Mamidipalli, Via Deshavagiri,
Hyderabad-500005.

42. Animal Quarantine and
Certification Service Station,
Delhi Gurgaon Road,
Kapashera Village
New Delhi.

43. Animal Quarantine &
Certification Service Station,
No. 1, Naickers Colony,
Pallavaram,
Madras-600043.

44. Animal Quarantine &
Certification Service Station,
10, H.L. Sarkar Road,
Bansdroni,
Distt. 24 Parganas,
West Bengal.

45. Animal Quarantine &
Certification Service Station,
C/o Central Poultry
Breeding Milk Colony,
Aarey Milk Colony
Bombay-400065.

46. Central Sheep Breeding Farm,
158-N Model Town,
Hissar, Haryana.

47. Central Poultry Breeding Farm,
Aarey Milk Colony,
Bombay-400065.

48. Central Poultry Breeding Farm,
Bhubaneswar-751012

49. Central Poultry Breeding Farm,
Hesserghatta,
Bangalore North.

50. Central Poultry Breeding Farm,
Industrial Area,
Chandigarh.

51. Central Duck Breeding Farm,
Hesserghatta,
Bangalore North.

52. Central Institute of Poultry
Production and Management,
Hesserghatta,
Bangalore North.

53. Random Sample Laying Test Unit,
Hesserghatta,
Bangalore North.

54. Random Sample Laying Test Unit,
Bhubaneswar-751012,

55. Random Sample Laying Test Unit,
C/o Aarey Milk Colony,
Bombay-400065.

56. Random Sample Laying Test Unit,
49/4, Urban Estate,
Gurgaon, Haryana.

57. Large Fodder Seed Production
Farm,
Hesserghatta,
Bangalore North.

58. Exploratory Fisheries Project,
Botwala Chambers,
Sir P. Mehta Raod,
Bombay-400001.

59. Central Institute of Nautical
Engineering and Training,
Dewans Road,
Ernakulam,
Cochin-682016.

60. Pre-investment Survey of Fishing
Harbours Project,
64, Palace Road,
Bangalore-560042.

61. Integrated Fisheries Project,
P.B. No. 1801,
Cochin-682016.

62. All India Soil and Land Use
Survey Organization,
I.A.R.I. Building,
New Delhi-110012.

63. Soil Conservation Research
Demonstration and
Training Centre,
Chatra, P.O. Jogbani,
Distt. Purnea, Bihar.

Public Sector Undertakings

1. State Farms Corporation of
India,
Beej Bhavan,
Pusa Institute Complex,
C.T.O. Building,
New Delhi-110012.

2. National Seeds Corporation,
Beej Bhavan,
Pusa Institute Complex,
C.T.O. Building,
New Delhi-110012.

3. Andaman and Nicobar Forest
Plantation Development
Corporation,
Port Blair.

4. Indian Dairy Corporation,
'Yashkamal',
7th Floor, P.O. Sayaigunj,
Baroda-390005.

5. Central Fisheries Corporation,
62, Rose Mary Lane, P.B. No: 86
GPO, Howrah, Calcutta.

Autonomous Organisations

1. National Cooperative
Development Corporation,
4, Siri Institutional Area,
Hauz Khas,
New Delhi-110016.

2. Animal Welfare Board,
First Main Road, Gandhi Nagar,
Madras-600020.

3. National Dairy Development
Board,
Anand, Gujarat.

4. Coconut Development Board,
Mahatma Gandhi Road,
Ernakulam,
Cochin-682011.

5. Indian Institute of Forest
Management,
E-5/120, Arere Colony,
Bhopal, M.P.

National Level Cooperative Federations

1. National Cooperation Union
of India,
No. 3, Siri Institutional Area,
Panch Sheel Marg,
New Delhi-110016.

2. National Agricultural
Cooperative Marketing
Federation of India Ltd.,
Saona Building,
54, East of Kailash,
New Delhi-110024.

3. National Cooperative Consumers
Federation Ltd.,
Deepali (5th Floor),
92, Nehru Place,
New Delhi-110024.

4. Indian Farmers Fertiliser
Cooperative Ltd.
34, Nehru Place,
New Delhi-110024.

5. National Federation Cooperative
Sugar Factories Ltd.,
Vikunth (3rd Floor),
82-83 Nehru Place,
New Delhi-110024.

6. The National Federation
of Industrial Cooperative Ltd.,
204, (2nd Floor),
Prabhat Kiran Building
Rajindra Place,
New Delhi-110008.

7. Petrofils Cooperative Ltd.,
New Delhi House,
27, Barakhamba Road,
New Delhi-110001.

8. National Heavy Engineering
Cooperative Ltd.,
16, Mahatma Gandhi Road,
Pune-411001.

9. The National Cooperative
Housing Federation Ltd.,
34, South Patel Nagar,
New Delhi-110008.

10. National Cooperative Dairy
Federation of India,
IDA House, Sector IV,
R.K. Puram,
New Delhi-110022.

11. National Federation of Urban
Cooperation Banks and Credit
Societies,
3, Netaji Subhas Marg,
Daryaganj,
New Delhi-110002.

12. The All India Federation
of Cooperative Spinning
Mills Ltd.,
14, Murzban Road, 2nd Floor,
Bombay-400001.

13. National Cooperative Land
Development Banks Federation,
Shivasakti, 2nd Floor,
B.C. Kher Road, Worli,
Bombay-400018.

14. National Federation of State
Cooperative Banks,
P.B. No. 9921, Garment House,
Dr. Annie Besant Road,
Worli,
Bombay-400018.

15. The All-India Industrial
Cooperative Banks Federation,
11, Bull Temple Road,
Basavanagudi,
Bangalore-560004.

16. The All-India Handloom Fabrics
Marketing Cooperative Society Ltd.,
G.P.O. Box No. 1121 (5th Floor),
56-58, Mittal Chambers,
Nariman Point,
Bombay-400021.

17. All-India Fishermen Cooperative
Federation Ltd.,
3, Siri Industrial Area,
Panch Sheel Marg,
New Delhi-110016.

18. Krishak Bharti
Cooperative Ltd.,
34, Nehru Place,
New Delhi-110024.

19. National Federation of
Labour Cooperation Ltd.,
4, Jantar Mantar Lane,
New Delhi-110001.

Agricultural Research & Education

1. National Academy of Agricultural
Research Management,
Hyderabad-500030.

2. Agricultural Scientists
Recruitment Board,
Hillside Road
Pusa,
New Delhi-110001.

MINISTRY OF COMMERCE

Research and Training Institute

1. Central Sericulture Station,
Behrampur-142101.

2. Central Sericultural Research
and Training Institute,
78, Devi Niwas, Nazarbad,
Mysore-857010.

3. Central Tasar Research Station,
Hebal,
Ranchi-834005.

4. Central Muga & Eri Research
Station,
Titabar-785632.

5. Central Coffee Research
Institute,
Chickmagalore,
Karnataka.

6. Rubber Research Institute
of India,
Rubber Board,
Kottayam-9.

7. UPASI Tea Research Station,
P.O. Cinchona-642106.

Autonomous Bodies

1. Indian Institute of Foreign
Trade,
Ashok Bhawan,
93, Nehru Place,
New Delhi-110019.

2. Indian Institute of Packaging,
Bombay.

3. Federation of Indian
Export Organisations,
PHD House, 3rd Floor,
4/2 Siri Institutional Area,
Hauz Khas,
New Delhi-110016

4. Indian Council of Arbitration,
Federation House
New Delhi-110001

5. Trade Development Authority,
Bank of Baroda Building
16, Parliament Street
New Delhi-110001

6. Marine Products Export
Development Authority,
Cochin, Kerala.

7. The Trade Fair Authority
of India,
Administrative Building
Pragati Maidan
New Delhi-110001

Public Sector Undertakings

1. The State Trading Corporation
of India,
Chandralok, 36, Janpath,
New Delhi-110001.

2. The Cashew Corporation of
India Ltd.,
P.B. 1216, M. Gandhi Road,
Cochin-682011.

3. The Projects & Equipment
Corporation Ltd.,
Hansalaya, 15, Barakhamba Road,
New Delhi-110001.

4. The Handicrafts and Handloom
Export Corporation Ltd.,
Lok Kalyan Bhavan,
11 A. Rouse Ave. Lane.
New Delhi-110001.

5. The Minerals & Metals
Corporation of India Ltd.,
Express Building,
9 & 10 B. Shah Zafar Marg,
New Delhi-110002.

6. Mica Trading Corporation,
137, Patliputra Colony,
Patna-800013.

7. The Export Credit and Guarantee
Corporation Ltd.,
Express Towers,
10th Floor,
Nariman Point,
Bombay-400021.

8. The Trading Corporation
of India,
225 F Acharya J.C. Bose Road,
Calcutta-700020

MINISTRY OF TEXTILES

Public Sector Undertakings

1. National Textile
Corporation Ltd.,
8th Floor, Surya Kiran Building,
Kasturba Gandhi Marg,
New Delhi-110001.

2. Cotton Corporation of
India Ltd.,
Air India Bldg., 12th Floor,
Nariman Point,
Bombay-400021.

3. Jute Corporation of
India Ltd.,
I, Shakespeare Sarani,
Calcutta-700071.

4. National Jute Manufacturers
Corporation,
Calcutta.

5. Handicraft and Handlooms
Export Corporation,
Lok Kalyan Bhavan,
11 A Rouse Ave Lane,
New Delhi-110001.

6. Central Cottage Industries
Corporation of India Ltd.,
Janpath,
New Delhi-110001.

7. North-Eastern Handicrafts
and Handlooms Development
Corporation,
Bomfyle Road,
Shillong-793001.

8. British India Corporation,
Kanpur.

9. National Handloom Development
Corporation.
Lucknow

Textiles Research Associations

1. Ahmedabad Textile Industry's
Research Association,
Polytechnic P.O.,
Ahmedabad-380015.

2. Bombay Textile Research
Association,
Lal Bhadur Shastri Marg,
G Lat Kopar (West).
Bombay-400086

3. South India Textile Research
Association,
Aerodrome P.O.,
Coimbatore-641014

4. North India Textile
Research Association,
Ghaziabad.

5. Silk and Artsilk Mills'
Research Association,
SASMIRA Marg, Worli,
Bombay-400025

6. Man-Made Textile Research
Association,
Surat.

7. Indian Jute Industry's
Research Association,
17, Taratola Road,
Calcutta-700053

8. Wool Research Association,
C/O SASMIRA,
Dr. Annie Besant Road,
Worli,
Bombay-400025

Export Promotion Councils

1. Handloom Export Promotion
Council,
Madras.

2. Apparels Export Promotion
Council,
4th Floor, Sahyog Building,
58, Nehru Place,
New Delhi-110019

3. Cotton Textiles Export
Promotion Council,
Bombay.

4. The Silk and Rayon Textiles
Export Promotion Council,
Bombay.

5. Wool and Woollens Export
Promotion Council,
Bombay.

MINISTRY OF COMMUNICATION

Main Ministry

1. Overseas Communication Service,
Videsh Sanchar Bhavan,
NIG Road, Fort,
Bombay-400001.

Public Sector Units

1. The Hindustan Teleprinters Ltd.,
Guindy,
Madras-600032.

2. Indian Telephone
Industries Ltd.,
16, Museum Road,
Bangalore-560001.

POSTS & TELEGRAPHS

Public Sector Unit

1. Telecommunication Consultants
India Ltd.,
Chiranjiv Tower, 3rd Floor,
43, Nehru Place,
New Delhi-110019.

R & D Unit

1. Telecommunication
Research Centre,
Khurshid Lal Bhavan,
Janpath
New Delhi-110001.

MINISTRY OF DEFENCE

1. Hindustan Aeronautics Ltd.,
Post Bag No. 1789,
Bangalore-560017.

2. Bharat Electronics Ltd.,
29, Race Course Road,
Bangalore-560001.

3. Bharat Earth Movers Ltd.,
J.C. Road,
Bangalore-560002.

4. Mazagaon Dock Ltd.,
Dock Yard Road,
Mazagaon,
Bombay-400010.

5. Garden Reach Shipbuilders
and Engineers Ltd.,
43/46, Garden Reach,
Calcutta-700024.

6. Goa Shipyard Ltd.,
Vasco-de-Gama,
Goa.

7. Praga Tools Ltd.,
6-68/32, Vivaduguda Road,
Secunderabad-500003.

8. Bharat Dynamics Ltd.,
10-3-30, Masab Tank,
Hyderabad-500028.

9. Misra Dhatu Nigam Ltd.,
Kanchan Bagh,
Hyderabad-500258.

Department of Defence Research & Development

1. Defence Research and
Development Organisation,
South Block,
New Delhi-110011.

DEPARTMENT OF DEFENCE

1. Institute of Avation Medicine
Indian Air Force,
P.O. Vimanpure,
Bangalore-560017.

MINISTRY OF EDUCATION & CULTURE

Organisations/Instituions

1. National Archives of India,
   Janpath,
   New Delhi-110001.

2. National Council of Educational
   Research and Training,
   NIE Campus,
   Sri Aurobindo Marg,
   New Delhi-110016.

3. National Institute of
   Educational Planning
   and Administration,
   17B, Sri Aurobindo Marg,
   New Delhi-110016.

4. Indian Institute of Advanced
   Study,
   Simla, H.P.

5. Indian Institute of Technology,
   (5 Nos.)

6. Indian Institute of Science,
   Bangalore.

7. Regional Engineering Colleges,
   (15 Nos.)

8. Indian Institute of Management,
   (3 Nos).

9. Technical Teachers' Training
   Institutes (4 Nos).

10. Indian School of Mines,
    Dhanbad, Bihar.

11. School of Planning and
    Architecture,
    I.P. Estate,
    New Delhi-110002.

12. National Institute of Training in
    Industrial Engineering,
    Bombay.

13. National Institute of Foundary
    and Forge Technology,
    Ranchi.

14. Indian Council of Social
    Science Research,
    IIPA Hostel Building,
    I.P. Estate,
    New Delhi-110002.

15. Indian Council of Historical
    Research,
    35, Faroz Shah Road,
    New Delhi-110001.

DEPARTMENT OF CULTURE

1. Archaeological Survey of India
   Janpath,
   New Delhi-110001

2. National Council of Science
   Museums,
   196, Gurusaday Road,
   Calcutta-700019.

3. Birla Industrial &
   Technological Museum,
   Calcutta.

4. Visvesvaraya Industrial &
   Technological Museum,
   Bangalore.

5. Nehru Science Centre,
   Bombay.

MINISTRY OF ENERGY

Petroleum: Public Sector Undertakings

1. Oil & Natural Gas Commission,
   Kaulagarh Road,
   Dehradun-248005.

2. Indian Oil Corporation Ltd.,
   Oil Bhavan,
   Janpath,
   New Delhi-110001.

3. Bharat Petroleum
Corporation Limited,
ECE House, Connaught Circus,
New Delhi-110001.

4. Hindustan Petroleum
Corporation Limited,
J. Tata Road,
Bombay-400020.

5. Cochin Refineries Limited,
P. Bag 1751,
Cochin.

6. Madras Refineries Limited,
Madras-600068.

7. Indo-Burma Petroleum
Company Limited,
11th Floor, Hindustan
Times House,
K. Gandhi Marg,
New Delhi-110001.

8. Engineers India Limited,
Bhikaji Cama Palace,
R.K. Puram,
New Delhi-110001.

9. Lubrizol India Limited,
Delater 9 A.S. Patkar Marg,
Bombay-400036.

10. Indian Petrochemicals
Corporation Limited,
P.O. Petrochemicals,
Vadodara.

11. Bongaigaon Refinery and
Petrochemicals Limited,
P.O. Dhaligaon,
Via New Bongaigaon Rly.Station,
Assam-783385.

12. Biecco Lawrie Limited
21, Netaji Subhas Road,
Calcutta-700001.

13. Bridge and Roof Co.
(India) Limited,
21, Nataji Subhas Road,
Calcutta-700001.

14. Petrofils Cooperative Limited,
New Delhi House,
Barakhamba Road,
New Delhi-110001.

Subsidiaries

1. Hydrocarbons India Limited,
Bank of Baroda Building,
7, Floor, Sansad Marg,
New Delhi-110001.

2. Indian Oil Blending Limited,
Pharpur,
Calcutta-700043.

3. Balmer Lawrie &
Company Limited,
P-4/1, Oil Installation Road,
Calcutta-700043.

Joint Sector Company

1. Oil India Limited,
17, Sansad Marg,
New Delhi-110001.

Other Organisations

1. Oil Coordination Committee,
Kailash Building,
26, K. Gandhi Margh,
New Delhi-110001.

2. Petroleum Conservation Research
Association,
709, Surya Kiran Building,
19, K. Gandhi Marg,
New Delhi-110001.

3. Central Institute of Plastic
Engineering & Tools,
Madras.

DEPARTMENT OF POWER

1. Central Electricity Authority,
Seva Bhawan, North Wing,
R.K. Puram,
New Delhi-110022.

Public Sector Undertakings

1. National Thermal Power
Corporation,
62, Skipper House,
Nehru Place,
New Delhi-110019.

2. National Hydroelectric Power
Corporation Ltd.,
Manjusha Building,
57, Nehru Place,
New Delhi-110019.

3. National Projects Construction
Corporation Ltd.,
Raja House,
13, Nehru Place,
new Delhi-110019.

4. Rural Electrification Corporation
Ltd.,
D.D.A. Building,
Nehru Place,
New Delhi-110019.

5. Damodar Valley Corporation,
Calcutta.

6. Bhakra Beas Management Board,
Chandigarh.

Other Organisations

1. Central Power Research
Institute,
Bangalore.

2. Power Engineers Training
Society,
Faridabad.

3. Central Board of
Irrigation and Power.
Malcha Marg,
Chanakyapuri,
New Delhi-110021.

DEPARTMENT OF COAL

Coal: Subsidiary Bodies

1. Nayveli Lignite Corporation,
Nayveli-607801,
Tamil Nadu.

2. Coal India Limited,
10, Netaji Subhas Road,
Calcutta-700001.

Public Sector Undertakings

1. Central Coalfields Ltd.,
Sanctoria, P.O.
Dishergarh-718333.

2. Western Coalfield Ltd.,
Bisesar House,
Temple Road,
Nagpur-440001.

3. Eastern Coalfield Ltd.,
Sanctorio, P.O.
Dishergarh-718333.

4. Bharat Coking Coal Ltd.,
Bhuggatdin Building,
Jharia-828111,
Dhanbad.

5. Central Mine Planning
Design Institute,
Gondwana Place,
Kanke Road,
Ranchi-834008.

6. Singareni Collieries
Company Ltd.,
Kothagudem, A.P.

Department of Non-Conventional Sources of Energy

1. Commission for Additional
Sources of Energy,
C.G.O. Complex,
New Delhi-110001.

MINISTRY OF FOOD & CIVIL SUPPLIES

Public Sector Undertakings

1. Food Corporation of India,
16-20 Barakhamba Road,
New Delhi-110001.

2. Central Warehousing
Corporation,
4/1 Siri Industrial Area,
Hauz Khas.
New Delhi-110016.

3. Modern Bakeries Ltd.,
Vasant Vihar,
New Delhi-110057

Research and Training Institutions

1. Indian Grain Storage Institute,
Hapur, U.P.

2. National Sugar Institute,
Kanpur-208017.

3. Institute of Hotel Management,
Catering Technology and Applied
Nutrition (4 Nos.)

4. Modern Bakeries Ltd.,
Vasant Vihar,
New Delhi-110057.

Bureau of Indian Standards

5. Manak Bhawan,
9, Bhadur Shah Zafar Marg,
New Delhi-110002.

MINISTRY OF HEALTH & FAMILY WELFARE

Prevention of Food and Adualteration Research Laboratories

1. Central Food Laboratory
3, Kyd Street,
Calcutta-700016.

2. Central Indian Pharmacopoeia
Laboratory,
Ghaziabad.

Medical Education Training, Research and Regularity Bodies

1. Medical Council of India
Medical Council Building,
Diwan-e-Galib Marg,
Kotla Road,
New Delhi-110002.

2. National Academy of
Medical Sciences,
C 11/16 Ansari Nagar,
New Delhi-110029.

3. Dental Council of India
Temple La Kotla Road,
New Delhi-110002.

4. India Nursing Council,
Combined Council Building,
Temple La Kotla Road,
New Delhi-110002.

5. Pharmacy Council of India
Temple La Kotla,
New Delhi-110012.

Premier Institutions

6. All India Institute of Medical Sciences,
Ansari Nagar,
New Delhi-110016.

7. Post-Graduate Institute
of Medical Education
& Research,
Sector-12,
Chandigarh-160001.

8. Jawaharlal Nehru Institute
of Post-Graduate Medical
Education and Research,
Pondicherry-605006.

9. V.P. Chest Institute
Post Bag No. 2101
Delhi-110007.

Research Institutes

10. National Institute of
Communicable Diseases,
22, Shamnath Marg,
Delhi-110006.

11. Central Research Institute
P.O. Kasaule, H.P.

12. National T.B. Institute,
8, Bellary Road,
Bangalore-560003.

13. Central Leprosy Teaching
and Research Institute
Post Box 1,
Chingleput-603001.

14. National Institute of Mental
and Neuro Sciences
P.O. Lal Bagh, Shantinagar,
Bangalore-560027.

15. All India Institute of Physical
Medicine and Rehabilitation
Clark Road, Mahalaxmi,
Bombay-400034.

16. All India Institute of
Speech Hearing
Maharaja College,
Centenary Hall,
Mysore-570005.

17. All India Institute of Hygiene
and Public Health,
110, Chittaranjan Avenue
Calcutta-700073.

18. Pasteur Institute of India
Conoor-643103.

19. Central Institute of Psychiatry
Ranchi, Bihar.

20. Central Health Education Bureau,
Nariman Bhawan,
New Delhi-110011

21. Central Bureau of Health
Intelligence,
New Delhi

22. Indian Council of
Medical Research,
Medical Enclave,
Ansari Nagar,
New Delhi-110029

Indian System of Medicine and Homeopathy

1. Central Council for Research
in Ayurveda and Siddha
Dharma Bhawan,
S-10 Green Park
Extention Market
New Delhi-110016

2. The Institute of History
of Medicine and Medical Research,
Tuglakabad, P.O. Madangir,
New Delhi-110062

3. National Institute of Ayurveda
Jaipur

4. Central Council for Research
in Unani Medicine
5 Panch Sheel Shopping Centre
New Delhi-110017

5. Central Council for Research
in Homeopathy,
10 Community Centre,
Basant Lok,
Vasant Vihar,
New Delhi-110057

6. National Institute
of Homeopathy
Calcutta.

7. Homeopathic Pharmacopoeia
Laboratory,
Ghaziabad.

8. Central Council for
Research in Yoga
and Neuropathy,
New Delhi-110001

9. Central Research Institute
for Yoga
New Delhi-110001

MINISTRY OF SOCIAL WELFARE

Autonomous and Subordinate Organisations

1. National Institute of
Health and Family Welfare
Near DDA Flats, Munirka,
New Delhi-110067.

2. International Institute of
Population Studies,
Deonar, Bombay-400088.

3. Hindustan Latex Ltd.,
Trivandrum.

4. Family Welfare Training
and Research Centre
381, Sardar Vallabhbhai
Patel Road
Bombay-400004.

MINISTRY OF HOME AFFAIRS

1. Bureau of Police Reserach and
Development,
8-168, Curzon Road Barracks,
New Delhi-110001.

2. Central Forensic Science
Laboratory,
Central Bureau of Investigation,
East Block VII, R.K. Puram,
New Delhi-110022.

3. Central Forensic Science
Laboratory,
30, Gorachan Road,
Calcutta-700014.

4. Central Forensic Science
Laboratory,
5-9-201/2, Chirag Ali Lane,
Hyderabad.

5. Institute of Criminology and
Forensic Science,
A-2/19, Safdarjung Enclave,
New Delhi-110029.

MINISTRY OF INFORMATION & BROADCASTING

1. Research Development,
All India Radio,
I.P. Estate, Ring Road,
New Delhi-110002.

2. Indian Institute of Mass
Communication,
D-13, N.D.S.E. Part II,
New Delhi-110049.

MINISTRY OF INDUSTRY

Attached Offices

1. Directorate General of Technical Development,
Udyog Bhavan,
New Delhi-110011.

2. Organisation of Development Commissioner for Small Scale Industries,
Nariman Bhavan,
New Delhi-110011

3. Bureau of Industrial Costs & Prices,
7th Floor, Lok Nayak Bhavan,
New Delhi-110003.

4. Directorate General of Industrial Contingency,
New Delhi.

5. Office of the Cement Controller,
7, Rajindra Place,
New Delhi-110008.

Subordinate Offices

1. Office of the Chief Controller of Explosives,
Nagpur.

2. Patent Office,
Nagpur.

3. Integrated Training Centre,
Nilokheri, Haryana

Public Sector Undertakings

1. National Industrial Development Corporation Ltd.,
Chankaya Bhavan,
Vinay Marg,
New Delhi-110021.

2. National Small Industries Corporation Ltd.,
New Okhla Industrial Estate,
New Delhi-110020.

3. Cement Corporation of India Ltd.,
59, Nehru Place,
New Delhi-110019.

4. Hindustan Photo Films Manufacturing Co. Ltd.,
Indu Nagar,
Ootacamund-643005.

5. Bharat Ophthalmic Glass Ltd.,
Durgapur-10,W.B.

6. National Instruments Ltd.,
1/1, Raja Subodh Chandra Mullick Road,
Calcutta-700032.

7. Instrumentation Ltd.,
Kota-324995.

8. Hindustan Cables Ltd.,
Rupnarainpur,
Burdwan Distt., W.B.

9. National Newsprint & Paper Mills Ltd.,
Nepanagar-450221., M.P.

10. Hindustan Paper Corporation Ltd.,
C-75, Park Street,
Calcutta-700016.

11. Hindustan Salts Ltd.
Parijat Bhavan,
Ashok Marg,
Jaipur-392998.

12. Sambhar Salts Ltd.,
Parijat Bhavan,
Ashok Marg,
Jaipur-392998.

13. Tannery and Footwear Corporation Ltd.,
Civil Lines,
Kanpur., U.P.

14. Bharat Leather Corporation Ltd.,
Noida, U.P.

15. Andrew Yule & Co. Ltd.,
Calcutta.

16. National Bicycle Corporation
of India Ltd.,
Bombay.

17. Cycle Corporation of India Ltd.,
Calcutta.

Other Offices/Bodies

1. Coir Board,
Cochin.

2. Central Boilers Board,
New Delhi.

3. National Productivity Council,
Institutional Area,
Lodhi Road,
New Delhi-110003.

4. Small Industries Extension
Training Institute,
Hyderabad.

5. Central Institute of Tool Design,
Hyderabad.

6. Institute for Design of Electrical
Measuring Instruments,
Bombay.

7. Central Tool Room & Training
Centre,
Calcutta.

8. Tool Room & Training Centre,
Ludhiana.

9. Hand Tool Institute,
Jullundhur.

10. Tool Room & Training Centre,
New Delhi.

11. National Institute of Design,
Paldi,
Ahmedabad.

12. National Federation of Industrial
Cooperatives,
New Delhi.

13. Cement Research Institute of India,
Ballabhgarh, (Haryana).

14. Indian Plywood Industries
Research Institute,
P.O. No. 2273, Tumkur Road,
Bangalore-560022.

15. Khadi & Village Industries
Commission,
3, Irla Road,
Ville Parle (W),
Bombay-400056.

16. Centre Pulp & Paper
Research Institute,
Dehradun, U.P.

17. Indian Rubber Manufacturers
Research Association,
Plot No. 88, Road 4,
Wagle Industries Estate,
Thana, Maharashtra

DEPARTMENT OF HEAVY INDUSTRY

Research Institutions

1. Automotive Research Association
of India,
Post Box No. 825,
Pune-411104.

2. Central Metal Forming Institute,
Hyderabad.

3. Central Machine Tool Institute,
Tumkur Road,
Bangalore-569923.

Public Sector Undertakings

1. Bharat Heavy Electricals Ltd.,
Hindustan Times House,
18-20, Kasturba Gandhi Marg,
New Delhi-110001.

2. Bharat Heavy Plates
and Vessels Ltd.,
P.O. Box No. 100,
Visakhapatnam-530012.

3. Bharat Pumps & Compressor Ltd.,
Naini,
Allahabad-211919.

4. Bharat Wagon Engineering
Co. Ltd.,
66, Patliputra Colony,
Patna-800013.

5. Braithwaite & Co. Ltd,
5, Hide Road,
Calcutta-700043.

6. Burn Standard Co. Ltd.,
10-C, Hungerford Street,
Calcutta-700017.

7. Heavy Engineering
Corporation Ltd.,
Ranchi-834004.

8. Hindustan Machine Tools Ltd.,
36, Cunningam Road,
Bangalore-560052.

9. Jessep & Co. Ltd.,
63, Netaji Subhas Road,
Calcutta-700001.

10. Lagan Jute Machinery Co. Ltd.,
Calcutta

11. Mining & Allied Machinery
Corporation Ltd.,
P.O. Durgapur-10

12. Richardson & Cruddas Ltd.,
Byculla Iron Works,
Post Bag No. 4503,
Bombay-400008.

13. Scooters India Ltd.,
P.O. Sarojini Nagar,
Lucknow-226008.

14. Triveni Structurals Ltd.,
Naini,
Allahabad-211919.

15. Tungabhadra Steel Products Ltd.,
P.O. Tungabhadra Dam-583225.

16. Engineering Project (India), Ltd.,
Kailash Building,
K. Gandhi Marg,
New Delhi-110001.

17. Maruti Udyog Ltd.,
Palam Gurgaon Road,
Haryana.

MINISTRY OF IRRIGATION

Attached Offices

1. Central Water Commissioner,
Seva Bhawan,
R.K. Puram,
New Delhi-110022.

2. Central Soil & Materials
Research Station,
Near IIT Hostel,
Outer Ring Road,
Hauz Khas,
New Delhi-110016.

Subordinate Organisations

1 Central Water & Power
Research Station,
Khadakvasla,
Pune-411024.

2. Central Ground Water Board,
Jammanagar House,
Mansingh Road,
New Delhi-110001.

3. Ganga Flood Control Commission,
Patna.

4. Sone River Commission,
Patna.

5. Bansagar Control Board,
Rewa.

6. Mahi Control Board,
Udaipur.

MINISTRY OF PETROLEUM, CHEMICALS & FERTILIZERS

Public Sector Undertakings

1. Fertilizer Corporation
of India Ltd.,
Madhuban, 55, Nehru Place,
New Delhi-110019.

2. Fertilizers & Chemicals
Travancore Ltd.,
Udyogmandal
Alwaye-683501.
Kerala.

3. National Fertilizers Ltd.,
20, Community Centre,
East of Kailash,
New Delhi-110065.

4. Rashtriya Chemicals and
Fertilizers Ltd.,
Marvali, Chembur,
Bombay-400074.

5. Madras Fertilizers Ltd.,
Manali,
Madras-600068.

6. Pyrites, Phosphates and
Chemicals Ltd.,
6, Community Centre,
East of Kailash,
New Delhi-110065.

7. Fertilizers (P&D) India Ltd.,
CIFT Building,
P.O. Sindri-828122,
Bihar.

8. Hindustan Fertilizer
Corporation Ltd.,
Nehru Place,
New Delhi-110019.

9. Hindustan Organic Chemicals Ltd.,
P.O. Rasayani-410207,
Maharashtra.

10. Hindustan Insecticides Ltd.,
Hans Bhavan,
Bahadur Shah Zafar Marg,
New Delhi-110002.

11. Indian Drugs &
Pharmaceuticals Ltd.,
Dhundahera Industrial Complex,
Dhundahera, Gurgaon Road,
Gurgaon-122001.

12. Hindustan Antibiotics Ltd.
Pimpri,
Pune-411018.

13. Smith Stanistreet
Pharmaceuticals Ltd.,
Calcutta-700014.

14. Bengal Chemicals and
Pharmaceuticals Ltd.,
6, Ganesh Chander Avenue,
Calcutta-700013.

15. Bengal Immunity Co. Ltd.,
153, Dharamtolla Street,
Calcutta-700013.

MINISTRY OF PLANNING

1. Central Statistical Organisation,
Sardar Patel Bhavan,
Sansad Marg,
New Delhi-110001.

2. Computer Centre,
East Block 10,
R.K. Puram,
New Delhi-110022.

3. National Sample Survey
Organisation,
Sardar Patel Bhavan,
Sansad Marg,
New Delhi-110001.

4. Indian Statistical Institute,
203 B.T. Road,
Calcutta-700035.

MINISTRY OF RAILWAYS

Public Sector Undertakings

1. The Rail India
Technical & Economic
Services Ltd.,
1st Floor, New Delhi House,
27, Barakhamba Road,
New Delhi-110001.

2. The Indian Railways
Construction Co. Ltd.,
Rattan Jyoti Building,
2nd Floor, 18, Rajindra Place,
New Delhi-110008.

R & D Unit

1. Research, Design & Standards
Organisation,
Manak Nagar,
Lucknow-226011.

Board

1. Central Board of Railway Research,
Rail Bhawan,
New Delhi-110001.

Production Units

1. Chittaranjan Locomotive Works,
Chittaranjan,
West Bengal.

2. Diesel Locomotive Works,
Varanasi-221001,
Uttar Pradesh.

3. Integral Coach Factory,
Perambur,
Madras-600038.

MINISTRY OF RURAL DEVELOPMENT

Institutions/Societies

1. Directorate of Marketing
and Inspection,
Faridabad.

2. National Institute of Rural
Development,
Hyderabad.

3. People's Action for
Development (India),
A-1, Nizamuddin West,
New Delhi-110013.

4. Council of Advancement of
Rural Technology,
New Delhi.

MINISTRY OF SHIPPING & TRANSPORT

Public Sector Undertakings

1. Shipping Corporation of India,
Shipping House,
245, M. Cama Road,
Bombay-400021.

2. Mogel Line Ltd.,
16, Bank Street,
Bombay-400023.

3. Hindustan Shipyard Ltd.,
Visakhapatnam-530005.
Andhra Pradesh.

4. Cochin Shipyard Ltd.,
P.B. 1653,
Cochin-682015.

5. Central Inland Water Transport
Corporation Ltd.,
4 Fairlie Place,
Calcutta-700001.

6. Indian Road Construction
Corporation,
Raja House,
Nehru Place,
New Delhi-110019.

MINISTRY OF STEEL & MINES

Steel: Public Sector Undertakings

1. Steel Authority of India Ltd.
Ispat Bhawan,
Lodhi Bhawan
New Delhi-110003.

2. Indian Iron & Steel Co. Ltd.,
ISCO House, 50 Chowringhee Road,
Calcutta-700071.

3. Metal Scrap Trade Corporation Ltd.,
225, F, Acharya Jagadish Bose Road,
Calcutta-700020.

4. Visvesvaraya Iron & Steel Ltd.,
Bhadravati-577301
Karnataka.

5. R&D Centre for Iron & Steel,
Hindustan Steel Ltd.,
Ranchi-834002.

6. National Mineral Development
Corporation Ltd.,
109, Surya Kiran Building,
Kasturba Gandhi Marg,
New Delhi-110001.

7. Manganese Ore (India) Ltd.,
3, Mount Road Ext.,
P.O. 34,
Nagpur-440001.

8. Metallurgical & Engineering
Consultants (India) Ltd.,
P.O. Hinoo,
Ranchi-834002.
Bihar.

9. Hindustan Steelworks
Construction Ltd.,
1, Shakespeare Sarani,
Calcutta-700071.

MINES: SURVEY AND BUREAU

1. Geological Survey of India,
27, Jawaharlal Nehru Road,
Calcutta-700013.

2. Indian Bureau of Mines,
New Industrial Building,
Nagpur-440001.

Public Sector Undertakings

1. Mineral Exploration
Corporation Ltd.,
Seminary Hills,
Nagpur-440006.

2. Bharat Aluminium Co. Ltd.,
Punji House,
18, Nehru Place,
New Delhi-110019.

3. Hindustan Copper Ltd.,
Indian Copper Complex,
Ghatsila, District,
Singhbhum-832102.

4. Hindustan Zinc Ltd.,
Z.S. Debari,
Udaipur,
Rajasthan-313024.

5. Bharat Gold Mines Ltd.,
Suvarna Bhavan, Oorgam,
P.O. Kolar Gold Fields,
Karnataka-563120.

6. Sikkim Mining Corporation,
Rangpo,
Sikkim.

MINISTRY OF TOURISM & CIVIL AVIATION

1. Technical Centre,
Research & Development Directorate,
Safdarjung,
New Delhi-110003.

2. Indian Institute of Tropical
Meteorology,
Ramdurg House,
University Road,
Pune-411005.

3. Indian Institute of Astrophysics,
Bangalore-560034.

4. Indian Institute of Geomagnetism,
Colaba,
Bombay-400005.

5. Indian Meteorological Department,
Mausam Bhavan,
Lodhi Road,
New Delhi-110003.

MINISTRY OF WORKS & HOUSING

Attached Office

1. National Building Organisation,
9, Wing Nirman Bhavan,
New Delhi-110001.

Subordinate Office

1. Town & Country Planning
Organisation,
'E' Block, Delhi Vikas Bhavan,
Indraprastha Estate,
New Delhi-110002.

Public Sector Undertakings

1. National Buildings Construction
Corporation Ltd.,
Integrated Office Complex,
Lodhi Road,
New Delhi-110003.

2. Housing Urban Development
Corporation, Ltd.,
18-A Jamnagar House,
New Delhi-110001.

3. Hindustan Prefab Ltd.,
Jangpura,
New Delhi-110014.

Statutory Bodies

1. Delhi Development Authority,
Vikas Minar,
I.P. Estate,
New Delhi-110002.

2. Delhi Urban Art Commission,
2nd Floor, Lok Nayak Bhavan,
Khan Market,
New Delhi-110003.

UNIVERSITIES

Andhra Pradesh

1. Andhra University
Waltair,
Visakhapatnam.

2. Andhra Pradesh Agricultural
University,
Rajendra Nagar,
Hyderabad-500030.

3. Andhra Pradesh Open University,
6-3-345, Somajiguda,
Hyderabad-500004.

4. Hyderabad University,
Hyderabad-500001.

5. Jawaharlal Nehru Technological
University,
Hyderabad-500008.

6. Kakatiya University,
Warangal-506009.

7. Nagarjuna University,
Guntur-522516.

8. Osmania University,
Hyderabad-500007.

9. Sri Krishnadevaraya
University,
Anantapur, A.P.

10. Sri Venkateswara
University,
Tirupati-517502.

Assam

11. Assam Agricultural University,
Jorhat-785013.

12. Dibrugarh University,
Dibrugarh-786004.

13. Gauhati University,
Gauhati-781004.

Bihar

14. Bhagalpur University,
Bhagalpur-812007.

15. Bihar University,
Muzaffarpur.

16. Birsa Agricultural
University,
Kanke,
Ranchi-834006.

17. Kameshwar Singh Darbhanga
Sanskrit University,
Darbhanga.

18. Lalit Narayan Mathila
University,
Darbhanga.

19. Patna University,
Patna-800005.

20. Rajendra Agricultural
University,
Samastipur-848125.

21. Ranchi University.
Ranchi.

Gujarat

22. Bhavnagar University,
Bhavnagar-364002.

23. Gujarat University,
Ahmedabad-380009.

24. Gujarat Agricultural
University,
Banas Kantha,
Sardar Krishinagar,
Dantiwada-385506.

25. Gujarat Ayurveda University,
Jamnagar.

26. Maharaja Sayajirao
University of Baroda,
Baroda-390002.

27. Sardar Patel University,
Vallabh Vidyanagar,
Via-Anand-388120.

28. Saurashtra University,
Rajkot-360005.

29. South Gujarat University,
P.B. No. 49,
Surat-395007.

Haryana

30. Haryana Agricultural
University,
Hissar-125004.

31. Kurukshetra University,
Kurukshetra-132119.

32. Maharishi Dayanand
University,
Rohtak-124001.

Himachal Pradesh

33. Himachal Pradesh
University,
Simla-171005.

34. Himachal Pradesh
Agricultural University,
Palampur-176062.

Jammu and Kashmir

35. Jammu University,
Jammu-180001.

36. Kashmir University,
Srinagar-196006.

37. Sher-e-Kashmir University
of Agricultural Sciences
and Technology,
P.B. No. 262,
Srinagar-190001.

Karnataka

38. Bangalore University,
Bangalore-560056.

39. Gulbarga University,
Gulbarga, Karnataka.

40. Karnatak University,
Dharwar-580033.

41. Mangalore University,
Light House Hill,
Mangalore-3.

42. Mysore University,
Mysore-570005.

43. University of Agricultural
Sciences,
Gandhi Krishi Vignana Kendra,
Bangalore-560024.

Kerala

44. Calicut University,
Calicut-673635.

45. Cochin University,
Cochin-682301.

46. Kerala University
Trivandrum-1.

47. Kerala Agricultural
University,
Main Campus,
Vellanikkara,
Trichur-51.

Madhya Pradesh

48. Awadesh Pratap Singh
University,
Rewa-486003.

49. Bhopal University,
Bhopal.

50. Devi Ahilya Vishwavidyalaya,
Indore-452001.

51. Jawaharlal Nehru Krishi
Vishwavidyalaya,
Jabalpur-482004.

52. Jiwaji University,
Gwalior-474002.

53. Rani Durgavati Vishwavidyalaya,
Jabalpur-482001.

54. Ravi Shankar University,
Raipur-492002.

55. Dr. Hari Singh Gour
Vishwavidyalaya,
Sagar-470003.

56. Indira Kala Sangeet
Vishwavidyalaya,
Khairagarh. M.P.

57. Vikram University,
Ujjain-456010.

Maharashtra

58. Bombay University,
Bombay-400032.

59. Konkan Krishi University,
Dapoli,
Ratnagiri-415712.

60. Mahatma Phule Krishi
Vidyapeeth,
Rahuri Distt.
Ahmednagar.

61. Marathwada University,
Aurangabad-431004.

62. Marathwada Krishi
Vidyapeeth,
Parbhani-2.

63. Nagpur University,
Nagpur.

64. Poona University,
Poona-411007.

65. Punjabrao Krishi
Vidyapeeth,
Akola-444104.

66. Shrimati Nathibai Damodar
Thakersey Women's University,
Bombay-400020.

67. Shivaji University,
Kolhapur-416004.

Manipur

68. Manipur University,
Canchipur,
Imphal-795003.

Meghalaya

69. North Eastern Hill
University,
P.O. Lower Lachumiere,
Shillong-793001.

Orissa

70. Berhampur University,
Berhampur-767007.

71. Orissa University of
Agriculture & Technology,
Bhubaneswar-451003.

72. Sambalpur University,
Jyoti Vihar, Burla,
Dt. Sambalpur-768017.

73. Shri Jagannath Sanskrit
Vishwavidyalaya,
Puri.

74. Utkal University,
Vani Vihar,
Bhubaneswar-751004.

Punjab

75. Guru Nanak Dev University,
Amritsar.

76. Panjab University,
Chandigarh-160014.

77. Punjab Agricultural
University,
Ludhiana.

78. Punjabi University,
Patiala.

Rajasthan

79. Jodhpur University,
Jodhpur.

80. Mohanlal Sukhadia -
Vishwavidyalaya,
Pratapnagar,
Udaipur-313001.

81. Rajasthan University,
Jaipur-302004.

Tamil Nadu

82. Anna University,
Guindy,
Madras-600025.

83. Annamalai University,
Annamalainagar-608101.

84. Bharathiar University,
Coimbatore-641041.

85. Bharathidasan University,
Tiruchirapalli.

86. Madras University,
Madras-600005.

87. Madurai Kamaraj University,
Madurai-625021.

88. Tamil University,
Tanjavur.

89. Tamil Nadu Agricultural
University,
Coimbatore-641003.

Uttar Pradesh

90. Agra University,
Agra-208004.

91. Aligarh Muslim University,
Aligarh-202001.

92. Allahabad University,
Allahabad-211002.

93. Avadh University,
Faizabad-224001.

94 Banaras Hindu University,
Varanasi-221005.

95. Bundelkhand University,
Jhansi-284003.

96. Chandra Sekhar Azad
University of Agriculture
& Technology
Kanpur-206002.

97. Garhwal University,
Srinagar (Garhwal).
Uttar Pradesh

98. G.B. Pant University of
Agriculture & Technology,
Pantnagar,
Nainital-263145.

99. Gorakhpur University,
Gorakhpur.

100. Kanpur University,
Kanpur.

101. Kashi Vidyapith,
Varanasi-221002.

102. Kumaon University,
Nainital-263001.

103. Lucknow University,
Lucknow-226007.

104. Meerut University,
Meerut.

105. Narendra Deo University of
Agriculture & Technology,
Faizabad-224001.

106. Rohilkhand University,
Bareilly-224001.

107. Roorkee University,
Roorkee-247672.

108. Sampurnanand Sanskrit
Vishwavidyalaya,
Varanasi.

West Bengal

109. Bidhan Chandra Krishi
Vishwavidyalaya,
Kalyani-741246.

110. Burdwan University,
Burdwan-713104.

111. Calcutta University,
Calcutta-700073.

112. Jadavpur University,
Calcutta-700073.

113. Kalyani University,
Kalyani, Dt. Nadia,
W.B.-741235.

114. North Bengal University,
Rajaram Mohanpur,
Darjeeling-700050.

115. Rabindra Bharati,
Calcutta-700050.

116. Vidva Sagar University,.
Midnapore (Camp),
88-A, Rash Behari Avenue,
Calcutta-700026.

117. Visva Bharati,
Santiniketan-731235.

Delhi

118. Delhi University,
Delhi-110007.

119. Jawaharlal Nehru
University,
New Mehrauli Road,
New Delhi-110067.

INSTITUTIONS DEEMED TO BE UNIVERSITIES

Andhra Pradesh

1. Central Institute of
English & Foreign Languages,
Hyderabad-500007.

2. Sri Sathya Sai Institute
of Higher Learning,
Prasanthi Nilayam-515134.

Bihar

3. Indian School of Mines,
Dhanbad-626004.

Gujarat

4. Gujarat Vidyapith,
Ahmedabad-380014.

Karnataka

5. Indian Institute of Science,
Bangalore-560012.

Maharashtra

6. Tata Institute of Social
Sciences,
Deonar,
Bombay-400088.

Rajasthan

7. Birla Institute of Technology
and Science,
Pilani-333031.

Tamil Nadu

8. Gandhigram Rural Institute,
Gandhigram,
Dt. Madurai-624302.

Uttar Pradesh

9. Dayalbagh Educational Institute,
Agra-282005.

10. Gurukul Kangri Vishwavidyalaya,
Hardwar,
Uttar Pradesh.

Delhi

11. Indian Agricultural Research
Institute,
Pusa Institute,
New Delhi-110012.

12. Jamia Millia Islamia,
New Delhi-110025.

13. School of Planning and
Architecture,
New Delhi-110002.

INSTITUTIONS OF NATIONAL IMPORTANCE

Andhra Pradesh

1. Dakshina Bharat Hindi Prachar
Sabha,
P.B. No. 68,
Hyderabad-500004.

Maharashtra

1. Indian Institute of Technology,
Powai,
Bombay-400076.

Tamil Nadu

3. Indian Institute of Technology,
Madras-600036.

Uttar Pradesh

4. Indian Institute of Technology,
Agricultural Gardens,
Kanpur-208016.

West Bengal

5. Indian Institute of Technology,
Kharagpur,
Midnapore-721302.

6. Indian Statistical Institute,
203, Barackpore,
Trunk Road,
Calcutta-700035.

Chandigarh

7. Post-graduate Institute of
Medical Education & Research,
Sector-12
Chandigarh-160012.

Delhi

8. All India Institute of Medical
Sciences,
Ansari Nagar,
New Delhi-110016.

9. Indian Institute of Technology,
Hauz Khas,
New Delhi-110029.

Appendix B

INDIAN TECHNOLOGIES READY FOR COMMERCIAL EXPLOITATION

CHEMICAL AND ALLIED INDUSTRY

CODE 100

***100:1. Trichlorobenzene**
(NCL, Pune—CSIR)

Trichlorobenzene is used as a solvent in the chemical manufacturing industry particularly dyes and intermediates. It can also be used as dielectric fluid, synthetic transformer oils, heat transfer medium. It is specially required for the manufacture of tetradifon. NCL process involves dehydrochlorination of non-gamma BHC in the presence of alkali.

***100:2. Terpineol**
(NCL, Pune—CSIR)

Terpineol is an important organic chemical used in perfumery, soaps, consmetics, etc. The process developed involves the conversion of alpha pinene to terpin-hydrate and terpin-hydrate to terpineol. SEU for this industry is 100 tonnes per annum.

***100:3. Tert-butyl catechol**
(NCL, Pune—CSIR)

Tert-butyl catechol is used as a stabilizer or polymerisation inhibitor in the synthetic rubber industry. The process is based on t-butyl alcohol and catechol. Minimum economical unit is 25 tonnes per annum.

***100:4. Potassium ethyl xanthate and potassium amyl xanthate**
(NCL, Pune—CSIR)

Potassium ethyl xanthate (PEX) and potassium amyl xanthate (PAX) are used as froth floatation agents in mineral industries. The process developed consists of mixing ethyl alcohol/amyl alcohol with potassium hydroxide solution and carbon disulphide. SEU for this industry is 150 tonnes of PAX per annum.

***100:5. Catechol**
(NCL, Pune—CSIR)

Catechol is used in the manufacture of t-butyl catechol which is an important antioxidant. The process involves the treatment of the polyvalent phenol fraction with benzene and crystallising pure catechol from the mixture. SEU for this industry is 45 tonnes of catechol per annum.

***100:6. Substitute for bostik sealant**
(NCL, Pune—CSIR)

Bostik compounds are used for sealing pressurised cabins and integral tanks of aircrafts. The process for making the compound consists of milling rubber with other ingredients and dissolving it in solvent along with RPFN resin.

***100:7. Can lining compound based on synthetic rubber latex**

(NCL, Pune—CSIR)

The lining compound, which is applied to the peripheral channel of the top and bottom ends of the can after drying, is mechanically interlocked with the flange of cylindrical can body. The process consists of continuous ball milling of dry and wet ingredients separately in definite proportion followed by mixing and straining.

***100:8. Thioglycollic acid**

(NCL, Pune—CSIR)

Thioglycollic acid is used in cosmetics in hair fixative. It is also used as an essential catalyst for bisphenol 'A' preparation. The process' consists of preparation of sodium slat of monochloroacetic acid and its reaction with sodium thiosulphate and hydrolysis of the intermediate product.

***100:9. Butyl titanate**

(NCL, Pune—CSIR)

Butyl titanate is used in insulating varnishes, fire and rust proof paints. It is also used as catalyst for polymerisation and condensation. Butyl titanate is prepared by the reaction of titanium tetrachloride with n-butanol in a suitable solvent.

***100:10. Adhesive for staple pins**

(NCL, Pune—CSIR)

Staple pins adhesive is used for joining the single metal wire staples on automatic machines. Its use can be extended to other fields also. This process consists of reacting polymeric resins with solvent and rolling it on jar mill in the presence of a small quantity of plasticizers.

***100:11. Sodium chlorate**

(CECRI, Karaikudi—CSIR)

Sodium chlorate finds extensive application as a starting material for the production of perchlorates. SEU for this industry is 600 tonnes of sodium chlorate per annum and estimated capital outlay is Rs 40 lakhs (1984).

***100:12. Potassium iodate**

(CECRI, Karaikudi—CSIR)

An electrochemical method for production of potassium iodate which finds application in manufacture of iodised salts has been developed. SEU for this industry is 6 tonnes of potassium iodate per annum.

***100:13. Sodium chloride AR & IP from marine salt**

(CECRI, Karaikudi—CSIR)

The manufacture of analytic reagent grade and India pharmaceutical grade sodium chloride must involve the quantitative removal of all the impurities from salt. The process involves the (i) removal of the bulk of soluble impurities, (ii) removal of residual soluble impurities from a saturated solution, and (iii) fractional crystallisation of sodium chloride.

***100:14. Potassium chlorate**

(CECRI, Karaikudi—CSIR)

Potassium chlorate is used in the manufacture of matches. The process worked out consists in oxidating sodium chloride to sodium chlorate followed by double decomposition with potassium chloride. SEU for the industry is 300 tonnes per annum and estimated capital outlay is Rs 45 lakhs (1985).

100:15. Zinc oxide from zinc waste

(CECRI, Karaikudi—CSIR)

Zinc oxide is used in rubber, paint, pharmaceutical and ceramic industries and the zinc metal is used in galvanising industry. The estimated capital investment for a plant producing 3 tonnes per day of zinc oxide and 2 tonnes per day of zinc metal with three shifts operation in a day and with 300 working days in a year is Rs 81 lakhs and 6,000 tonnes of zinc metal is about Rs 1.6 crore.

100:16. Manganous chloride

(CECRI, Karaikudi—CSIR)

Manganous chloride is used as a catalyst in the chlorination of organic compounds, as a dryer in paints, in printing inks and dyeing textile, as a growth stimulant in fertilizer. The process involves the dissolution of reduceed manganese ore in hydrochloric acid followed by purification and crystallisation. SEU for the industry is 330 TPA.

***100:17. Ammonium perchlorate**
(CSMCRI, Bhavnagar—CSIR)

The new process makes use of platinum as anode material for electrolytic oxidation of sodium chlorate to sodium perchlorate and the double decomposition of sodium perchlorate with either ammonium chloride or ammonium sulphate. SEU for this industry is 1.5 tonnes of ammonium perchlorate per month.

***100:18. Methyl anthranilate from phthalic anhydride**
(RRL, Bhubaneswar—CSIR)

Methyl anthranilate is used in perfumery industry and also in flavour work especially in synthetic grape juice. The demand for this chemical is estimated to be between 15 and 20 tonnes per annum and some quantity out of this is imported. The raw materials, plant and equipment required for the production of this chemical are all indigenously available. The suggested optimum capacity of the plant is 4.2 tonnes per year.

***100:19. Synthetic fine calcium silicate**
(CSMCRI, Bhavnagar—CSIR)

Synthetic fine calcium silicate finds use as reinforcing filler. The product prepared by a novel process from lime, active silica and aluminium trichloride is uniform in respect of chemical composition. SEU for this industry is 300 tonnes of product per annum.

100:20. Chemical grout
(MERI, Nasik, Govt. of Maharashtra)

Chemical grout is used for reducing leakage in water bearing strata e.g. tunnels, dams, reservoirs and other water bearing structures. The process developed consists in dissolving a mixture of ammonium chloride and melamine in formaldehyde solution.

100:21. Potassium silicate
(CSMCRI, Bhavnagar—CSIR)

Potassium silicate is required in the manufacture of electrodes and as a binder, adhesive filler and coating in the manufacture of T.V. tubes. CSMCRI process envisages the ion exchange technique for the manufacture of potassium silicate. The raw materials are potassium chloride and sodium silicate. Suggested economic unit for this industry is the production of 60 tonnes of potassium silicate per annum.

***100:22. Calcium carbonate whiting, (micron size) from calcite**
(CSMCRI, Bhavnagar—CSIR)

Calcium carbonate whiting is extensively used in paints, pigments, papers, printing inks and as a filler in various moulded plastic and rubber articles. It is not the substitute for precipitated calcium carbonate which is very light and porous. SEU for the industry is 1,500 tonnes per annum.

***100:23. Hydrazine hydrate**
(RRL, Hyderabad—CSIR)

Hydrazine hydrate finds use in the manufacture of INH, in boiler feed water as an antioxidant. It is raw material for the production of sodium azide. Its major potential use is in the manufacture of blowing agents. The capacity of SEU is 300 tonnes of 100% hydrazine hydrate per year. The capital outlay of such a plant is estimated to be around Rs. 90 lakhs, excluding the cost of land and building.

***100:24. Surgical grade plaster of Paris**
(RRL, Jammu—CSIR)

Surgical grade plaster of Paris is used in orthopaedic department for fractures etc. Plaster of Paris is obtained by the beneficiation wet process of substandard mineral available in Jammu region.

100:25. Fire retardant paints
(CBRI, Roorkee—CSIR)

Wood is a building material invariably used in all types of buildings, but no treatment is known which will prevent wood from charring at elevated temperature. The institute has developed a fire retardant paint which can be easily applied to the surface.

100:26. First-aid Chemical foam extinguisher

(CBRI, Roorkee—CSIR)

First-aid chemical foam extinguishers designed for upright operation are not available in India. The advantage of having a first-aid chemical foam extinguisher capable of upright operation is obvious. Such an equipment has been developed by the institute meeting the specifications and characteristics as specified in IS: 933-1967.

100:27. Gelatin optical filter

(IIEM, Calcutta)

These filters are used in instruments like calorimeter, flame photometer etc. Care is taken in selecting the dyes to get some sort of a monochromatic band pass, which singly or in superimposition with others give a good monochromatic light of half band width.

100:28. Rescalite

(CMRS, Dhanbad—CSIR)

Rescalite is used in self-rescue mask, gas mask in carbon monoxide atmosphere in mines, gas plants, chemical plants, etc. The new process uses less expensive and more active catalyst than what is available in the market namely Hopcalite used in the canisters. A capital outlay of about Rs. 1 lakh would be required for building and machinery and cost of production is estimated at Rs. 100 per kg of the catalyst which can be fitted in 12 rescue canisters. The process can be taken up with advantage by the firms already manufacturing chemical product of this nature.

100:29. Separation of protein fraction from blood plasma

(IIEM, Calcutta)

Human plasma as such has found a variety of clinical applications. The invention relates to the process of separation of protein fraction from human and animal blood plasma or serum by a simple method of precipitation with progressively increasing concentration of mixture of hydrogen phosphates of some known salts at room temperature. The process has been tested on a sample of 200 ml of human blood plasma and final product has been tested to B.P. and U.S.P. specifications.

*100:30. Silica gel FIA grade

(IIP, Dehradun—CSIR)

FIA grade silica gel is used for estimation of aromatics, oleofines and saturates in gasolines and kerosene. The process envisages the mixing of sodium silicate solution which hydrochloric acid at a regulated rate to desired pH. The mixture is then transferred to aging chamber. The aged material is then dehydrated and dried. This is then washed, dried and ground in a ball mill.

*100:31. Methyl anthranilate and ethyl anthranilate from isatoic anhydride

(RRL, Bhubaneswar—CSIR)

Methyl anthranilate and ethyl anthranilate are used in perfumery industry. The process developed consists in reacting isatoic anhydride with methyl and ethyl alcohol from reaction mixture by distilliation. The process has been worked out on one kg of the product per batch. SEU for this industry is for the production of 4.45 tonnes of methyl and ethyl anthranilate per annum.

*100:32. Isatoic anhydride

(RRL, Bhubaneswar—CSIR)

Isatoic anhydride is a versatile organic intermediate useful in the manufacture of several industrially important chemicals related to anthranilic acid. The process involves the oxidation of phthalimide by chlorine or sodium hypochlorite. Acidification of reaction mixture precipitates isatoic anhydride. The process has been studied on 4 kg per batch scale. Phthalimide, sodium hydroxide, chlorine are the main raw materials. SEU for the industry is for the production of 10 tonnes of the product per annum.

100:33. Chromic oxide

(RRL, Bhubaneswar—CSIR)

Chromic oxide is used as a lapping medium in ball bearing industry. It is also used in glass, lens etc. The process consists in heating the mixture of potassium bichromate and a polysachride. The reaction mass after leaching with water is washed, dried and heated to suitable temperature to produce required grade of chromic oxide. SEU for the industry is 6 TAP.

100:34. Black stamp cancellation ink

(NPL, New Delhi—CSIR)

The ink is used by Posts and Telegraphs Department for cancellation of stamps. The present composition uses cheaper raw materials i.e. non-edible vegetable oil which is much cheaper and better than petroleum based oil now being used.

SEU is 100 tonnes/annum; and fixed capital is Rs. 1.75 lakhs.

100:35. Dehydrated castor oil fatty acid

(RRL, Hyderabad—CSIR)

This finds extensive application in surface coating industries. They are an excellent source and dienoic acids and are used in the preparation of dimer acid which are important intermediates for polyamide resins. Capacity for SEU for this process is 1,000 tonnes of DCO fatty acid per annum working 3 shifts per day.

100:36. Precipitated calcium carbonate

(CSMCRI, Bhavnagar—CSIR)

Precipitated calcium carbonate is widely used as filler in paints and paper industry. The process developed is continuous carbonation process. SEU for the industry is for the production of 10 tonnes of products per annum.

100:37. Low temperature zinc phosphating

(CECRI, Karaikudi—CSIR)

Phosphate coatings are widely employed to improve adhesion of paint to iron and steel surfaces. The new phosphating formulations based on zinc phosphate can be operated at ambient temperature. SEU for the industry is for the production of 500 litres of formulation per day.

100:38. Zinc silicate green phosphor

(CECRI, Karaikudi—CSIR)

Zinc silicate green phosphor is mainly used in green fluorescent tube light. Zinc oxide, silica, manganese sulphate, silica dishes are the main raw materials. SEU for the industry is for the production of 3 tonnes of product per annum.

100:39. Oxalic acid from the bark of terminalia species

(FRI, Dehradun-Min. of Agriculture)

Oxalic acid is an important industrial chemical for textile and pharmaceutical industry. The process developed is for the manufacture of oxalic acid from the bark of terminalia species. It involves the treatment of course powder of bark with dilute mineral acid. Oxalic acid is found to be about 95% pure. The yield is about 15-20%.

100:40. Pour point depressant (flow improver)

(RRL, Jorhat—CSIR)

This is a chemical formulation, which when added to the waxy petroleum crude helps the crude flow better during pipe line transportation over long distances.

*100:41. Formulation of self regulating high speed chrome salt

(CECRI, Karaikudi—CSIR)

The conventional chromic acid, sulphuric acid being replaced by new salts and switch over to the use of modern chrome baths is taking place due to many advantages. CECRI has developed catalyst additive mixture. This when added along with chromic acid gives the modern SRHS chrome bath which has been observed to have a performance similar to the bath made out of imported salt. SEU for this industry is 19.5 metric tonnes of the catalyst-addition mixture per annum.

100:42. Anodising of aluminium and its alloys

(CECRI, Karaikudi—CSIR)

Anodising of aluminium and its alloys is a process of building up natural oxide which offers protection to the basic metal from corrosion. Further colouring of anodising, aluminium gives an aesthetic appeal, and decorative value. The process in vogue for anodising employs direct current for building up oxide film. The process developed at CECRI envisages the utilisation of alternating current by suitable modifications of the anodising electrolytes, thus reducing the cost of electrical equipment. The SEU for this industry is for anodising 18 sq. m. aluminium per day.

100:43. Methyl chlorosilanes

(NCL, Pune—CSIR)

Methyl chlorosilanes (MCS) are the raw material for the production of linear and cross linked organopolysiloxanes for the synthesis of numerous modified products. The end products of methyl chlorosilanes will be silicon fluids, oils, rubber resins, emulsions, dispersions, etc. These products find application in almost all industries such as textiles, pharmaceutical, food, rubber, electrical insulation, synthetics, etc.

The estimated cost of the project for a capacity to produce 1,000 tonnes per annum of methyl chlorosilanes is Rs. 5-6 crores (1984).

100:44. Membrane technique in industrial processing

(IIT, Bombay)

At present conventional waste treatment technology (mostly based on biochemical reactions) is used in waste effluent treatment for pollution control without water recovery and the process is capital intensive as well as operational cost is very high. Similarly, in concentration/separation fields, conventional systems like evaporators/distillation operation for handling dilute streams like sweet (Dilute glycerine of 7-10% concentration) or sugar solution or glue/collagen, is extremely energy intensive and as such operational costs are very high. The process developed uses the membrane technique (reverse/osmosis/filtration) in industrial processing. RO/UF technology could be used as a cost effective technique in separation/concentrated desalination of brakish polluted water for drinking water/industrial process operations and in industrial effluent treatment along with pollution abatement, and water/chemicals recovery. Depending upon the systems used, products that would be obtained could be reusable water from industrial effluent, useful chemicals as concentrated from diluted feeds like glycerine/sugar, etc. SEU would be 2 to 3 TPD effluent treatment unit for pollution control along with soda recovery (in paper mill). The unit could also be used for concentration, separation fields in various chemical industries like sugar, glycerine, glue, etc., with proper change in the RO/UF membrane.

100:45. B P P S

(RRL, Jorhat—CSIR)

This is a plant growth promoting soil additive. The process involves the fermentation of selective microorganisms depending on the need. The organisms are collected in a broth comprising of nutrient media containing jagrin, superphosphate, potassium phosphate, magnesium sulphate, etc. After sterilisation the mask is inoculated with different strengths as required in different soil conditions as well as the characteristics of the plant. Suggested economic unit is 1,000 litres per day in three shifts and the fixed capital of plant and machinery is Rs. 7 lakhs and expected profit amount in 20%.

100:46. High purity magnesia and magnesium carbonate from grade magnesite ore

(NML, Jamshedpur—CSIR)

NML has developed a technology for the production of high purity magnesia and magnesium carbonate from low grade magnesite. The process involves calcination of magnesite followed by its hydration and pressure carbonation. The products—magnesia and basic magnesium carbonate—conform to the specification for pharmaceutical and rubber industries etc. CC for 3.5 tonnes per day of magnesia and magnesium carbonarre is Rs. 139.5 lakhs.

100:47. Instant gel

(ERDL, Pune—DRDO)

A new gelling agent for hydrocarbon fuels has been developed by laboratory. This product is superior in gelling properties to the existing gelling agents used in incendiary bombs and flame thrower fuels. It has a good demand in defence. Capital outlay for 30 tonnes per year production has been estimated at Rs. 37.04 lakhs.

100:48. Castor stearin and stearic acid from castor oil

(RRL, Hyderabad—CSIR)

It is being used in industries like rubber compounding greases, cosmetics, textiles, etc. The process consists of simultaneous hydrogenation and dehydration of castor oil to obtain castor sterain. The estimated fixed capital on plant is Rs. 600 lakhs for producing 9000 TPA castor stearin and 7650 TPA strearic acid.

100:49. Castor olein & oleic acid from castor oil

(RRL, Hyderabad—CSIR)

It is being used in industries like nonionic surfactants, wetting agents, ore floatation carbon paper, stencil paper, etc. The optimum suggested plant capacity is for castor olein 9000 TPA, oleic acid 7630 TPA, and glycerol 810 TPA. The tentative cost of plant & machinery is Rs. 600 lakhs.

100:50. Reclamation of used and unserviceable transformer oils

(CPRI, Bangalore)

CPRI, Bangalore, had developed a simple and economical process using indigenous materials for reclaiming transformer oil suitable for use in industrial establishment and State Electricity Board. The cost of reclamation by the CPRI process works out to 10% of the cost of new transformer oil and thus the process proves to be very economical. SEU for this industry is for putting up 1,500 litres capacity transformer oil reclamation plant. The total investment required to put up such a plant has been estimated at Rs. 2 lakhs.

100:51. Necelone

(NCL, Pune—CSIR)

A new speciality perfumery chemical from longifolene. Process consists of isomerization of longifolene and acylation into acetyl allisolongifolene. SEU is 500 kg per annum. Investment is around Rs.60,000.

100:52. Chrome lignite

(RRL, Jorhat—CSIR)

A variety of speciality chemical additives and formulations are being used under various trade names for the successful exploitation of oil and gas reserves. Chrome lignite is one of the vital drilling mud additives which is extensively and universally used to achieve and maintain desired rheological properties of water based drilling mud at high temperature. It is particularly used to fortify lignosulfonate heated muds when drilling temperatures above 140°C are encountered. The plant and machinery cost for a 800 TPA capacity plant would be around Rs. 28 lakhs.

100:53. Etching composition suitable for etching on glass

(NPL, New Delhi—CSIR)

The laboratory has developed a special chemical composition suitable for etching marking permanent and opaque letters on glassware and glass instrument. The composition can also be used for obtaining fine graticules giving sharp lines which do not require any filling material for getting contrast when projected. The technology is so simple and economical that it does not require any sophisticated plant & machinery. Estimated capital outlay is Rs. 30,000 excluding the cost of land and building.

100:54. Low nickel room temperature bright nickel plating salt formulation

(CECRI, Karaikudi—CSIR)

The special formulation is used for bright nickel plating and has advantages over the conventional Watts' nickel solution that it operates at lower concentration of nickel and lower temperature range 30-40°C compared to 55-60°C recommended for bright Watts' bath. For a plant capable of producing 30 tonnes per annum (300 working days a year on single shift a day) of the low nickel room temperature plating salt fixed capital on plant and machinery would be around Rs. 50,000 whereas the working capital would be around Rs. 5 lakhs.

Following processes are also available for licensing:

*1. **Luminescent grade zinc sulphide**
(CECRI, Karaikudi—CSIR)

2. **Citronellol oil distillation**
(RRL, Jorhat—CSIR)

3. **Substitute for Canada balsam**
(NBRI, Lucknow—CSIR)

4. **Device for intra ovarian injection in large animals**
(CDRI, Lucknow—CSIR)

*5. **New apparatus for distillation of essential oil and perfumed water**
(NBRI, Lucknow—CSIR)

*6. **Metol**
(NBRI, Lucknow—CSIR)

7. **Silver powder and silver conducting paint**
(NPL, New Delhi—CSIR)

8. **Molecular sieves zeolite**
(RRL, Jorhat—CSIR)

9. **Electro-organic coatings over mild steel and alumimum articles**
(CECRI, Karaikudi—CSIR)

10. **Titanium substrate insoluble anodes**
(CECRI, Karaikudi—CSIR)

*11. **Chemical treatment of injector cones of steam locomotive**
(DMSRDE, Kanpur—DRDO)

*12. **Substitute for Eider down**
(DMSRDE, Kanpur—DRDO)

*13. **Dry chemical powder for extinguishing fires involving metals**
(DIFR, New Delhi—DRDO)

MARINE CHEMICAL INDUSTRY

CODE 101

*101:1. Bromine

(CSMCRI, Bhavnagar—CSIR)

Bromine is used in the manufacture of inorganic bromides for use in pharmaceutical and photographic industries. Organic bromides are used as fumigants. The process is based on sea bittern which is available from salt works. SEU for this industry is 90 tonnes per annum.

101:2. Light basic magnesium carbonate

(CSMCRI, Bhavnagar—CSIR)

Light basic magnesium carbonate finds application in rubber industry and in the manufacture of cigarette and in quality papers. The process developed utilises sea bittern as the raw material which is available in plenty. SEU for this industry is 30 tonnes per annum.

101:3. Potassium chloride, epsom salt and sodium sulphate from mixed salt

(CSMCRI, Bhavnagar—CSIR)

Potassium chloride, besides being used as a fertilizer, is the basic raw material for the manufacture of industrially useful salts. There are no potash deposits in India and our entire requirements are met by import. The new process is for the recovery of potassium chloride from sea bittern. The SEU is for making 1,000 tonnes potassium chloride, 260 tonnes epsom salt and 900 tonnes sodium sulphate.

*101:4. Potassium schoenite

(CSMCRI, Bhavnagar—CSIR)

Potassium schoenite is a double sulphate of potassium and magnesium. It contains 22-24% potassium oxide and 90% magnesium oxide. It is being used as potash fertilizer in western countries. Potassium schoenite is specially suitable for crops that do not tolerate chlorine such as tobacco, potato, sugarcane, etc. It is prepared from mixed salts obtained by evaporation of sea bitterns. Suggested economic unit for this industry is 10 tonnes of potassium schoenite per day.

101:5. Sodium sulphate from Sels mixts
(CSMCRI, Bhavnagar—CSIR)

Sodium sulphate is used in the manufacture of paper. A small quantity is required for detergent, in glass and textiles industry. The new process is based on the utilisation of Sels mixts which is a by-product of marine salt industry of the country. Suggested optimum capacity of the plant is 2,400 tonnes of sodium sulphate per annum.

***101:6. Alginic acid/sodium alginate**
(CSMCRI, Bhavnagar—CSIR)

Sodium alginate is used in large quantities in food and textile industry. The process developed is simple and consists of treatment of cleaned and dry seaweeds with hydrochloric acid followed by washing and extracting with mild alkali.

According to the fresh estimates the SEU for this industry is 200 kg/day.

PLASTICS, RESINS AND PAINTS INDUSTRY

CODE 102

***102:1. Alumina ceramics**
(CGCRI, Calcutta—CSIR)

Alumina ceramics are used for grinding media, kiln furniture, ignition boat, tubes and rods, laboratory wares, cylindrical pins (insulating), thermostat switches, crucibles, sparkplugs, flow controllers (oil drilling), wire drawing nozzles, TIG nozzles, chemical slurry nozzles, friction rings, etc. Estimated capital outlay for 270 tonnes of the product per annum is Rs. 95 lakhs.

***102:2. Low lead wirewound resistors enamel**
(CGCRI, Calcutta—CSIR)

Vitreous enamels are used for applying an impervious coating on wirewound resistors. The process envisages lesser use of lead oxide which is an imported material. SEU for this industry is 6 tonnes of enamel per annum and estimated capital outlay is Rs. 2 lakhs (1984).

102:3. Synthetic inorganic pigment
(RRL, Bhubaneswar—CSIR)

Synthetic inorganic pigment is used as an ingredient in paints. It can also be used in belt polishes. The process involves dissolving the iron oxide in water. The slurry is then mixed with ferrous sulphate solutions, sulphuric acid and potassium ferrocyanide. The process has been studied on 0.5 kg per batch scale. SEU for the industry is 15 TPA.

***102:4. Synthetic iron oxide red & black**
(RRL, Bhubaneswar—CSIR)

Iron oxide is used as inorganic pigment. The new process involves the addition of milk of lime to the solution of ferrous chloride resulting in the precipitation of ferrous hydroxide. Air is bubbled in to oxidize the ferrous hydroxide to the magnetic oxide (black) stage. The black oxide is suitably roasted to get oxide of iron. Suggested economic unit for this industry is the production of 60 tonnes of synthetic iron oxide black and red per annum.

***102:5. Pigment graue red oxide of iron**
(RRL, Bhubaneswar—CSIR)

Red oxide of iron finds application in paints, plastics, rubber, ceramic and other industries. The by-product sodium sulphate obtained in the process is extensively used in paper industry. The process developed utilises waste pickle liquor of steel plant.

SEU for this industry is 300 tonnes of the product per annum.

102:6. Red lead red oxide primer

(CECRI, Karaikudi—CSIR)

Red lead oxide primer has application or all steel structures i.e. bridges, towers, tanks rail coaches, exposed to atmosphere. The new process consists in mixing red lead red oxide pigment in different ratios in double boiled linseed oil.

102:7. Paint stripper

(CECRI, Karaikudi—CSIR)

Paint stripper developed by CECRI, can be used in removing old paints (stoved enamel, rubber paints, bituminous and coal tar based paints). The process for making paint stripper is simple. Suggested optimum capacity of the plant is 1,50,000 litres of paint stripper per annum.

102:8. Inhibitor for prevention of corrosion cooling water system

(CECRI, Karaikudi—CSIR)

The inhibitor is useful for control of corrosion in cooling water systems. The process consists in thoroughly mixing four different chemicals in solid form in proper ratio. SEU for the industry is 30 TPA.

*102:9. Lacquer for corrosion prevention

(CECRI, Karaikudi—CSIR)

Lacquer can be used for the preservation of simple metal assemblies e.g. crane shaft, crankshafts, hand tools, etc. It may also be suitable for the preservation of metal stores during storage and transit. The process envisages the dissolution of asphalt or coal tar pitch, resin and corrosion inhibitor. Suggested economic unit for this industry is for producing 60,000 litres of corrosion preventive lacquer per annum.

102:10. Calcium chromate/iron oxide primer

(CECRI, Karaikudi—CSIR)

Primers can be used on all types of steel structure such as bridges, towers, tanks and griders. Calcium chromate, iron oxide, magnesium silicate, epoxy ester, solvents are the main raw materials. SEU for this industry is 135 tonnes of primer per annum.

102:11. Cement paints

(CBRI, Roorkee—CSIR)

Cement paints are widely used as decorative and water proofing exterior coating for surfaces such as cement concrete, cement plaster, asbestos cement sheet, brick works, etc. These paints can be used in interior surfaces also. The process is simple and is based on indigenously available materials.

The capital investment for a plant having a production capacity of 2 tonnes per day is estimated at Rs. 1.15 lakhs.

102:12. Silicate based water proofing formulation

(CBRI, Roorkee—CSIR)

Cement paints currently in use in protective coatings for plasters are porous in nature and therefore can be considered as a best damp proof. Only silicons are known to give a water repellent film but these are very costly. As a suitable water proofing formulation has been developed.

The capital investment for a plant capable of producing one tonne/day has been estimated at Rs. 67,000.

102:13. Dibutyl phthalate (DBP) and dioctyl phthalate (DOP)

(NCL, Pune—CSIR)

DBP and DOP are used as plasticizers in vinyl resins and other synthetic resins. The process consists of esterification of phthalic anhydride with butyl alcohol/2 ethyl hexanol in the presence of a suitable catalyst.

102:14. Anion exchange resins from melamine

(NCL, Pune—CSIR)

Anion exchange resins are used for complete or partial deionisation or demineralisation of solutions where it is desired to remove dissolved ionic substances completely. The process consists methyline tetramine under acidic conditions. SEU for this industry is 12 kg resins per day.

*102:15. Dimethyl and diethyl phthalates (DMP & DEP)

(NCL, Pune—CSIR)

DMP and DEP are used as plasticizers. The process involves the reaction of phthalic anhydride with methyl alcohol/ethyl alcohol in the presence of a catalyst. SEU is 1,500 tonnes each of DMP and DEP per annum.

102:16. Butyl octyl phthalate (BOP)

(NCL, Pune—CSIR)

Butyl octyl phthalate (BOP) is used as plasticizer. In many non-electrical applications BOP has been found to be substitute of dioctyl phthalate (DOP). The process consists of esterification of phthalic anhydride with n-butanol and 2-ethyl hexanol in the presence of a suitable catalyst. SEU for this industry is 3,000 tonnes per annum.

102:17. Spatter resistant paint

(DLW, Varanasi—Miny. of Rlwys.)

While welding, the weld metal spatter falls on the base metal adjacent to the area being welded. These globules of metal stick on to the base metal and have to be ground off. In certain applications, these globules get dislodged due to vibrations and get access in to the various piping systems and create operational difficulties. By painting the adjacent area with the spatter resistant paint to welding, the spatter can be easily removed by simple brushing.

*102:18. Rigid polyurethane foam

(DSL, Delhi—DRDO)

Rigid polyurethane is used in packing electronic components. It has also got insulation applications, buoyancy applications, electrical applications etc. Defence Science Laboratory has developed two types of resins. One is based on castor oil and other is based on aleuritic acid. Rigid polyurethane foam is easily prepared by reacting one of these resins with diphenyl di-isocyanate-methane compositions. SEU for this industry is 100 kg resin per day.

102:19. Anticorrosion packaging paper

(CECRI, Karaikudi—CSIR)

The anticorrosion packaging paper is used for the prevention of corrosion of all types of ferrous engineering items. The process envisages the dissolution of inhibitive chemicals either in water or solvents and coating the same on paper. SEU for the industry is for coating 1200 m^2 paper (coated from aqueous bath) per day.

102:20. Zinc sodium silicate primer

(CECRI, Karaikudi—CSIR)

Primers are used for the protection of steel surfaces. The process developed consists in reacting zinc dust with sodium silicate and addition of red lead. SEU for the industry is for the production of 150 tonnes of primer per annum.

102:21. Zinc rich primer

(CECRI, Karaikudi—CSIR)

Zinc rich primer in organic medium may find application in the protection of steel structures in marine and industrial environments. The improved zinc pigmented paint developed at CECRI has better performance. SEU for the industry is for the production of 150 tonnes of product per annum.

102:22. Zinc phosphate pigment as anti-corrosive primer

(CECRI, Karaikudi—CSIR)

Zinc phosphate finds application in the preparation of anticorrosive primer. The process consists in adding suitably diluted orthophosphoric acid to the slurry of zinc carbonate. SEU for the industry is for the production of 300 tonnes of products per annum.

102:23. Chemical milling primer paint system for aircraft grade aluminium alloys

(NCML, Bombay—DRDO)

NCML has developed chemical milling primer paint system which consists of one coat of chloroprene based pigmented primer followed by one coat of PVC primer and subsequently followed by five coats of vinyl based varnish. This is used for protection of chemically treated aircraft grade aluminium alloys during chemical milling operations carried out in alkali bath of 12-17% concentration and a temperature of 70-90°C. Exposed areas produce smooth contours of desired dimensions and shape. The system protects unexposed surfaces during chemical milling operations and at the end of the operation, facilitates easy peeling of the system. An annual requirement of 10 tonnes has been estimated.

102:24. Mica based textured coating

(CGCRI, Calcutta—CSIR)

Mica based textured coating are used for protection and decoration of most exterior surfaces. It is ideal for metal, concrete masonry and wood surfaces and can be used for buildings, hotels, schools etc. SEU is Rs. 1.5 lakhs/litre and capital outlay Rs. 9.6. lakhs.

102:25. Vinyl ester resin

(IIT, Delhi & VSSC, Trivandrum)

By far the most largest use of vinyl ester resin is in making corrosion resistant equipment, pipe, ducts, scrubbers, flue stacks and storage tanks. These resins can be fabricated into composition e.g. FRP which is used by the chemical processing, petroleum, agriculture, food industries. The advantages of this system are excellent chemical resistance, low maintenance requirements, design flexibility and ease of installation. A variety of vinyl esters can be produced depending on the type of epoxy used. In the present case a bisglycidyl metha-acrylic acid. Based on the investment for a plant of capacity 500 TPA, the product cost works out to be Rs. 85 per kg.

102:26. Furan resin

(SPU, Gujarat & VSSC, Trivandrum)

Furan resin has unique properties, as matrix resin for glass fibre reinforced composite (comparable to conventional phenolics), better resistance to alkali, better dielectric properties even under humid condition. The tensile and flexural strength of this type of resin are comparable to that of commercial phenolic resins. The above mentioned properties enable furan resins for application in products used in electrical equipment susceptible for breakdown under humid conditions, for parts of chemical equipment where higher resistance to alkali is required. The resin can also be used as binder for abrasives. It is produced by poly condensation between phenol and furfuraldehyde in presence of a basic catalyst. Any existing phenolic resins manufacturing unit should be able to produce furan resin in the same plant without any additional equipment. Based on an investment for a plant the product cost works out to be Rs. 48 per kilogram.

102:27. HET acid based polyester resins

(SRI, Delhi)

The HET acid based polyester resins are flame retardant/self extinguishing polyester resins. The characteristic features of these resins are that the translucency of these resins is inherent in them the smoke produced by these resins are less toxic than conventional polyester resins, and their superior chemical resistance.

102:28. Preparation of water displacing rust preventive oil

(CECRI, Karaikudi—CSIR)

Water displacing rust preventive oil finds application in temporary protection of ferrous surfaces. The composition removes the water from the surface and forms a thin oily film which prevent rusting.

The process developed involves the mixing of various ingredients in certain proportion and manner. The investment on plant and machinery of a unit of capacity 30,000 litres per year (1 shift) would be around Rs. 60, 000, however, the investment on working capital would be about Rs. 4 lakhs (1986).

102:29. Zinc ethyl silicate primer

(CECRI, Karaikudi—CSIR)

This primer can be used for the protection of all types of steel structures in marine environments in place of conventional primers like and oxide/zinc chromate, red lead, etc. which do not give adequate protection and therefore require finishing paints. The cost of protection by this primer is less than the conventional primers.

The process developed consists of mixing zinc dust with ethyl silicate binder along with dibutyl phthalate titanium dioxide and antimony trioxide and the consistency is adjusted with xylen. The suggested optimum capacity is 150 tonnes per year (300 working days) for which investment towards plant and machinery is about Rs. 60,000 whereas working capital will be about Rs. 10 lakhs (1986).

***102:30. Polyurethane coating**
(NCL, Pune—CSIR)

The process is for the manufacture of shellac polyester urethane compositions for use in textiles, water proofing, adhesives, paints, varnishes electrical insulating varnishes.

***102:31. Rust prevention composition (phosphating jelly)**
(CECRI, Karaikudi—CSIR)

Rust prevention composition can be used to phosphate steel structure after removing rust and scale to prevent the structures from rusting before painting. The jelly is based on plant carbohydrates and mineral acid. SEU for this industry is 630 tonnes of jelly per annum.

Following process is also available for licensing:

1. **Red mud, zinc chromate primer and red mud barium potassium/barium chromate primer**
   (DMSRDE, Kanpur—DRDO)

INSECTICIDES AND PESTICIDES INDUSTRY

CODE 103

103:1. Diethyl toluamide
(NCL, Pune—CSIR)

Diethyl toluamide is a powerful mosquito and general purpose insect repellent. The product is especially useful for armed forces. Process consists of oxidation of xylene to toluic acid which is condensed with diethylamine to get the final product. SEU is 10 tonnes per annum (equivalent to 1 lakh tubes of 75 gm each containing 5% active material).

***103:2. Atrazine**
(NCL, Pune—CSIR)

Atrazine is used as herbicide in maize and sugarcane crops. The process developed involves the interaction of cyanuric chloride with ethylamine and isopropylamine. SEU for this industry is 60 tonnes of atrazine per annum.

***103:3. Simazine**
(NCL, Pune—CSIR)

Simazine is used as a herbicide in maize and sugarcane crops. The process for the production of simazine is the interaction of cyanuric chloride with ethylamine under suitable conditions. SEU for this chemical is 100 tonnes per annum.

***103:4. 2:2-Dichloropropionic acid (Dalapon)**
(NCL, Pune—CSIR)

Dichloropropionic acid (Dalapon) is used as a selective weedicide, mainly for the control of grasses in sugarcane, beet root, maize, potato and other similar crops. Its reaction resembles that of 2:4 D. Process consists of chlorination of propionic acid at higher temperature. The product is vacuum distilled and converted into sodium salt. SEU for this industry is 300 tonnes per annum.

***103:5. 2-chloroethyl-trimethyl ammonium chloride/chlorocholine chloride/ccc/cycocel chloromequat**
(NCL, Pune—CSIR)

2-Chloroethyl-trimethyl ammonium chloride/chlorocholine chloride/ccc/cycocel chloromequat is an important plant growth regulator widely used to increase flowering, ball frequency and yields of cotton crop. Treatment of wheat plants with cycocel results in short still straw. It also prevents lodging and increases tillering in wheat plants. It imparts drought cold and salt resistances in soyabean, cabbage, and tomato crops. The process consists of reacting trimethylamine and ethylene dichloride in the presence of solvent under suitable conditions. SEU for this industry is 30 tonnes per annum.

*103:6. Maleic hydrazide

(NCL, Pune—CSIR)

Maleic hydrazide is a versatile plant growth regulator principally used for stopping the sprouting of onions and potatoes in storage, as a suckericide for tobacco cultivation and increasing sugar content in beetroots etc. Process consists of treating hydrazine hydrate with maleic anhydride in the presence of mineral acids. SEU for this industry is 10 tonnes per annum and capital outlay for such a plant is Rs. 6.28 lakhs.

*103:7. Endosulfan

(NCL, Pune—CSIR)

Endosulfan is a broad spectrum synthetic organic contact pesticide useful for the control of pests and mites which infest fruits and vegetables etc. Endosulfan has very low toxicity towards mammals. NCL process consists of reacting hexachloro-cyclopentadiene (HCCP) with cis-2 butene, 1, 4 diol to obtain endosulfan alcohol which is then reacted with thionyl chloride to yield endosulfan.

*103:8. Dimethoate

(NCL, Pune—CSIR)

Dimethoate is a systematic organophosphorus insecticide, acaricide characterized by its low toxicity to human beings and other warm blooded animals. It is a well established product and is sold under the trade names "rogor, fosfamid, terimetion, rexion, etc". It is widely used and is effective for control of a wide range of insects and mites on many vegetables, cotton sorghum, wheat, lemon, oranges, apples, pears, safflower, grape fruit and ornamental plants, etc. Starting from phosphorus pentasulphide and methanol technical grade dimethoate is produced by 5 stage reaction. SEU for this industry is 150 tonnes per annum.

*103:9. Ethephon

(NCL, Pune—CSIR)

Ethephon is an important plant growth regulator. By its application rubber latex yields can be increased by 200 to 300 per cent. It can change the female-male flower ratio and this eventually yields more fruits in many plants. It is also used for maturing and ripening fruits in many plants.

The process consists of preparation of this (2 chloroethyl) phosphite from phosphorus trichloride and ethylene oxide. Phosphite is isomerised to digester of phosphonic acid which is then de-esterified to yield ethephon. SEU for this industry is 6 tonnes per annum.

*103:10. Carboxin (Vitavax)

(NCL, Pune—CSIR)

Carboxin (vitavax) is a systematic fungicide for the seed treatment of cereals against smuts and bunts and for the treatment of cotton, peanuts and vegetables against Rhizoctonia. The fungicide is highly specific and effective against pathogens without injury to hosts. It has practically no toxicity. Aceto acetanilide is chlorinated in benzene medium with sulphuryl chloride to obtain monochloro aceto acetanilide which on further condensation and cyclisation, yields carboxin. SEU for this industry is 30 tonnes per annum.

*103:11. Ethion

(NCL, Pune—CSIR)

Ethion is used as an insecticide, acaricide and belongs to organophosphorus group of pesticides used for controlling aphids, mites, scales, thrips and leafhoppers etc., on a wide variety of food, fibre and ornamental crops. It is used mainly in tea industry and also for cotton crops. Starting from ethyl alcohol and phosphorus pentoxide, ethion is prepared involving three stage reactions. SEU is 150 tonnes per annum.

*103:12. Diazinon

(RRL, Hyderabad—CSIR)

The main applications of diazinon are in rice, fruit trees, vineyards, sugarcane, corn, tobacco, potatoes, horticulture crops for a wide range of sucking and leaf eating insects. The process consists of preparation of 2-iso-propyl-4-methyl-6-hydroxypyrimidine from isobutronitrile and condensation of O,O diethyl, chloro thiophosphate with 2-isopropyl-4-methyl-6-hydroxypyrimidine to produce diazinon. The estimated demand would be around 200 TPA.

Process optimised on 3-5 kg/batch scale. Process offered along with basic design with guarantee on raw material consumption, quality of product and capacity of plant.

*103:13. Monocrotophos

(RRL, Hyderabad—CSIR)

This belongs to the group of organophosphorous insecticides with an antichlorines terase activity. It plays an important role in pest management on crops like cotton, sugarcane, groundnut, tobacco, etc. N-methyl acetoacetamide is dehydrated and reacted with trichloro-acetaldehyde and chlorinated. The product is filtered, the filterate being stripped.

The chloro product dissociated is concentrated which is dissolved in dichloroethane. The mass after reaction is concentrated.

103:14. Copper sulphate

(RRL, Bhubaneswar—CSIR)

Copper sulphate has its most extensive use in agriculture. It is the most active ingredient of the fungicides used for the control of various plant diseases. The process developed envisages the use of waste sulphuric acid from detergent plant. Suggested economic unit for this industry is 400 tonnes per annum of copper sulphate.

103:15. Phosphamidon

(RRL, Jorhat—CSIR)

This chemical is used as an insecticide in rice, cotton, potatoes, corn, sorghum, tomatoes, cauliflower, apples and cucumbers, etc. The important pests controlled are aphids, stenborus luno hugs, leafhoppers, budworms, etc. A process has been developed to prepare this compound from N.N.—diethylaceto acetamide. The capital outlay for a plant to manufacture 50 tonnes year is about Rs. 60 lakhs.

*103:16. Monocrotophos 36% WSC (formulation)

(RRL, Hyderabad—CSIR)

Monocrotophos is a fast acting insecticide with both systematic and contact action used against a wide range of pests including mites, sucking insects, boll worms on a variety of crops as cotton citrus, sugarcane, peanuts, fruits and vegetables. Generally formulation units are put up for formulating more than one technical pesticide. However, estimated cost of plant and equipment of a 500 kg/day general purpose formulation unit for liquid formulation is about Rs. 4 lakhs. The cost of raw material required per kg of product is Rs. 101.

*103:17. Dichlorovos (DDVP) technical

(RRL, Hyderabad—CSIR)

This is a common name for O, O-Dimethyl 2, 2-dichlorovinyl phosphate on organophosphorous pesticides. It is used as a household and public health fumigant against diptheria and mosquitoes and for crop protection against sucking and leaf mining insects. The SEU as suggested by laboratory is 150 tonnes per annum is estimated at Rs. 74 lakhs excluding the cost of land and building.

*103:18. Dichlorovos (DDVP) 76% EC

(RRL, Hyderabad—CSIR)

This is effective as a fumigant stomach and contact poison, especially against diptheria and mosquitoes for crop protection against sucking and leaf mining insects. Generally formulation units are put up for formulating more than one technical pesticides. However, the estimated cost of plant and equipment of a 500 kg per day general purpose formulation unit for liquid formulation is approximately Rs. 4 lakhs. The cost of raw material required per kg of product is Rs. 132.15.

***103:19. Diazinon 20% EC**

(RRL, Hyderabad—CSIR)

Diazinon is an organophosphorous insecticide with acaricidal properties. It is used in the control of flies, cockroaches, bed bugs, silver fish fleas and ants. Generally formulation units are put up for formulating more than one technical pesticides. However, estimated cost of plant and equipment of a 500 kg/day formulation unit is approximately Rs. 4 lakhs.

***103:20. Trimethyl phosphite**

(RRL, Hyderabad—CSIR)

This is used as an intermediate in the manufacture of pesticides, such as monocrotophos DDVP, naled, phosphamidon etc. Chemicals are mixed and fed into a reactor. The slurry nutrilized and the organic layer is dehydrated under vaccum, solvent recovered is reused. Crude TMP is purified on distillation.

103:21. Quinalphos 25% EC

(RRL, Hyderabad and Jorhat—CSIR)

It is potent against pests of cotton, paddy, groundnut, tobacco, fruits, vegetables and other crops. It is effective against both biting and sucking insects as well as mites and plant hoppers. The SEU as suggested by RRL, Hyderabad, is 150 tonnes per annum. The plant and equipment cost is estimated at Rs 6 lakhs (1987). The cost of raw material required per kg of the product is Rs. 79.

103:22. Nicotine sulphate from tobacco & tobacco waste

(NCL, Pune—CSIR)

Nicotine sulphate is a powerful insecticide, effective against many forms of boring, gnawing and sucking insects that attack plant life. Its insecticidal action is exercised by contact, ingestion and suffocation. It does not induce immunity in pests as certain other insecticides do, and unlike some of these, it does not present a toxic hazard to humans in the concentration in which it is commonly used. The process consists of mixing tobacco power with lime and extracting water. Nicotine in the aqueous solution is further extracted with kerosene. The kerosene extract of nicotine is treated with sulphuric acid to obtain nicotine sulphate solution (containing 40% nicotine). Approximate investment on putting up a plant for treating one tonne per day of tobacco or tobacco waste containing 2% nicotine would be around Rs. 3.2 lakhs.

AGRO-BASED INDUSTRY

CODE 200

***200:1. Speciality paper**

(RRL, Hyderabad—CSIR)

Speciality paper consists of filter papers, drawing papers, document and bond papers etc. The process makes use of waste raw materials from garment making industry, ginning industry etc. Apart from home demand there is great potential for export of these varieties of speciality papers. SEU for this industry under small scale sector is 100 tonnes per annum.

200:2. Dialdehyde starch

(CECRI, Karaikudi—CSIR)

Dialdehyde starch finds wide applications in tanning industry, plywood industry and in tobacco industry. The process is more economical than the conventional single stage process. SEU is 120 tonnes of dialdehyde starch per annum.

***200:3. Extraction of strychnine and brucine from nux vomica seeds**

(RRL, Bhubaneswar—CSIR)

Strychnine and strychnine sulphate are used as rodenticide. Brucine and its salts are useful for denaturing alcohol and as analytical agent for separating optical isomers. Nux vomica seeds, benzene, sodium hydroxide, sulphuric acid are the main raw materials.

***200:4. Expansion joint filler from coconut pith**
(CRRI, New Delhi—CSIR)

Expansion joint fillers can be used for concrete pavements, bridge decks and other structures. A know-how for the manufacture of expansion joint filler has been developed from coconut pith which is a waste product of coir industry. SEU for this industry is 250 sq. ft. (2″ thickness) of board per day. Estimated capital outlay, excluding the cost of building is Rs. 94,400.

***200:5. Pure catachine from khair trees**
(FRI, Dehradun)

Pure catachine is known to have medicinal value and finds application in a number of pharmacological preparations. The invention involves the isolation of pure catachine by treating the raw materials with a suitable solvent under optimum conditions of temperature and concentration. SEU for this industry is 1,500 kg of catachine per annum.

Following process is also available for licensing:

***1. Carboxy methyl starch**
(SRI, Delhi)

FOOD INDUSTRY

CODE 201

***201:1. Dehulling of sesame seed**
(CFTRI, Mysore—CSIR)

Dehulled sesame seed is used in preparation of confectionery items like chikkis, candies and also in bakery products. Commercial sesame seed is cleaned to remove extraneous matter and then treated in hot caustic soda lye, decutilled, washed and dried. SEU for this industry is 1500 tonnes of clean seeds per annum.

***201:2. Tamarind juice concentrate**
(CFTRI, Mysore—CSIR)

A technique for the production of a wholesome and convenient product of tamarind juice concentrate which finds used in culinary preparations has been developed. SEU for this industry is one tonne of product per day. Estimated capital outlay for the unit is Rs. 13 lakhs. The cost of production is estimated at Rs. 7,550 per tonne.

***201:3. Fruit bars**
(CFTRI, Mysore—CSIR)

Fruit bars are prepared from pulpy fruits such as mango, banana, guava and papaya which are abundantly available in the country. Fruit bars, besides being more nutritious can easily be packed and distributed. The process developed is simple and involves the drying of fruit pulps after mixing it with suitable ingredients. SEU for this industry is 100 kg of product per day.

***201:4. Protein isolate from groundnut and soyabeans**
(CFTRI, Mysore—CSIR)

Isolated protein with low fat contents is superior to protein concentrates with respect to colour flavour and taste. Protein isolate can be used in the preparation of ready mixes, hydrolysates, textured protein preparations, toning to milk, protein enriched bakery products, protein based beverages, ice cream, confectionery products etc. Capacity of SEU is 5 tonnes of protein isolate per day.

***201:5. Garlic powder**
(CFTRI, Mysore—CSIR)

Garlic powder is used as a condiment in food preparations and the use of garlic powder is well established in European countries and in USA. Capacity for SEU for this process is 225 kg powder per day (750 kg garlic bulbs).

*201:6. Utilisation of limes for the production of pectin oil (distilled) and citrates

(CFTRI, Mysore—CSIR)

Pectin is used in the fruit and vegetable preservation and in pharmaceutical industry. Lime waste is a rich source of pectin. The oil and citrate, which are by-products, are in good demand which is being met at present by imports. All these products have export potential. The major lime producing states in the country are Andhra Pradesh, Assam, Gujarat, Maharashtra, Tamil Nadu, Karnataka and Punjab. It is suggested that the grower of limes may set up production of pectin oil and citrates.

*201:7. Wax emulsion

(CFTRI, Mysore—CSIR)

Extension of storage life of easily perishable fruits/vegetables is an important aspect for a country like India with tropical climatic conditions. The wax emulsion when applied to fresh, healthy, mature fruits/vegetables protects them against excessive moisture loss, higher respiration rate, heat build up and thermal decomposition. SEU for this process is 100 gallons per day (12 hours operation).

*201:8. Mustard powder

(CFTRI, Mysore—CSIR)

This is being used for the preparation of mustard paste, table mustard, etc. The process involves splitting and dehusking the graded seeds. The husk and cotyledons are screened and air classified into different fractions where the cotyledons are ground to required fineness. The SEU is 500 kg of power per day.

*201:9. Papain (IP) & papain concentrate from papaya

(CFTRI, Mysore—CSIR)

Papain (IP) is widely used in pharmaceutical industries for protein hydrolysates, lacto peptones etc. in the food industries for clarification of juices, beer, etc., textile industries for degumming, in leather industries for tanning. Papain concentrate is used in pharmaceuticals and food industries where products of higher purity without odour are required. Capacity for SEU for this process is 30 kg of papain (IP) and 6 kg of papain concentrate per shift.

17*201:10 Refined cocoamass

(CFTRI, Mysore—CSIR)

It is a flavouring agent for ice-cream, cakes confectioners, etc. The cocoabeans after fermentation and grading are roasted under optimum controlled conditions, cooled and shelled. The beans are refined in a roller mill and then moulded and cooled. Capacity for SEU of this process is 200 kg of cocoamass per day of our stuff.

*201:11. Food preservation flask

(RRL, Bhubaneswar—CSIR)

Food preservation flask developed by RRL Bhubaneswar can preserve cooked food for a period of three days without refrigeration of preservation chemicals added to it. The principle involves the initial sterilisation of the food in steam and then storing under vacuum by subsequent condensation of the steam inside the flask.

*201:12. High purity salt

(CSMCRI, Bhavnagar—CSIR)

High purity common salt finds applications as table, dairy and kitchen salt. The process developed is simple, cheap and is based on solar evaporation. The purity of salt is 99.3%.

*201:13. Table salt and dairy salt

(CSMCRI, Bhavnagar—CSIR)

A know-how for the manufacture of table salt and dairy salt has been developed. The salt obtained by the process is clamied to have all characteristics of table and dairy salt. SEU for this industry is 300 tonnes of salt per annum.

*201:14. Sodium stearoyl-2 lactylate (SSL)

(CSMCRI, Bhavnagar—CSIR)

SSL is food grade emulsifier and is extensively used as a dough conditioner and antistaling agent. The process is based on neutralising lactic acid simultaneously polymerising and esterifying with stearic acid under an atmosphere of carbon-dioxide.

Estimated demand is 400 to 500 tonnes per year. The product proved satisfactory in baking tests. The work has been carried out on a scale of 2 kg/batch. Process is available on 'as is basis'.

*201:15. High pungent fraction & colour from Indian chilli oleoresin

(RRL, Trivandrum—CSIR)

The main product high pungent oleoresin having a scoville heat value of over one million heat units, can be used for pharmaceutical purposes while the chilli colour free from pungent can be used for edible purpose and also can be added to pickle making. The residue from chilli seed having a protein content 27-29% can be used as a fertiliser or as animal feed. SEU of this industry is one tonne of whole chilli per day of two shifts.

*201:16. Dry packed green pepper

(RRL, Trivandrum—CSIR)

To overcome the disadvantages of poor texture of dehydrated green pepper of the weight and high packaging cost of canned and bottled green pepper, RRL, Trivandrum has developed a process on cured green pepper packed under moist condition. This finds use in many Middle East and European countries, USA & Japan as a garnishing spice. Capacity for SEU for this process is 250 kg per day for 60 days of one shift/day.

*201:17. Flavour blends for orange & lemon-lime carbonated beverage

(CFTRI, Mysore—CSIR)

The orange beverage prepared from the orange flavour is similar to 'FANTA' an item formally imported. A crystal clear lemon-lime beverage prepared is similar to 'Seven up', a popular beverage in USA. The deterpenated citrus oil finds use in flavouring confectionery, bakery goods & pharmaceuticals while the by-product terpene rich citrus oil can be used as a flavouring agent in cosmetic & toiletries and also as a solvent in perfumery and thinner for paints. The capacity for SEU of this process is 4 units of lime-lemon flavour blend per day of one shift. One unit of flavour blend will yield 10,000 bottles of finished beverage.

201:18. Compounded asafoetida

(CFTRI, Mysore—CSIR)

In powder/tablet form being uniform in quality finds use in the culinary preparation for various flavouring purposes. The SEU as suggested by CFTRI for this industry is 60 tonnes per annum.

201:19. Apparatus for decortication, decuticling and degerming of groundnut pods

(OTRI, Anantapur—ICAR)

In order to improve the quality of oil and oil cakes it is necessary to remove skin and germs from groundnut kernels. The conventional decortication of groundnut pods yields groundnut kernels containing skin and germs intact and also undecorticated pods. The process developed at OTRI, Anantapur envisages the removing of shells, the skin and the germs in single step. The kernels thus obtained will yield oil and edible oil cake.

201:20. White pepper powder from black pepper

(RRL, Trivandrum—CSIR)

White pepper is liked for its mellow flavour, high pungency, low fibre and high starch content and above all white colour. In the improved method, the processing is done at a dry state so much so the black skin is separated and can be used for oleoresin extraction. The SEU as suggested by Regional Research Laboratory, Trivandrum, for this industry is 300 kg of black pepper per day of one shift.

*201:21. Decuticling of sesame seeds

(OTRI, Anantapur—ICAR)

Cuticle of sesame seeds contains many undesirable constituents such as toxic acid, acid soluble ash and crude fibre. Besides, the brown and black colour of the cuticles render the sesame products less attractive and the oil as well as the meal produced from the whole seed are of bitter taste. The conventional process of sesame seed is cumbersome and also time consuming. The process developed envisages the soaking of cleaned seed in water with soaked seeds in cold are then passed through a mechanical screw press followed by washing off the freed cuticles and drying of the wet decuticled seeds. An additional expenditure of Rs.10,000 to Rs.30,000 for the mechanical screw pressing depending upon the rated capacity will be required by the firm already engaged in sesame seed processing.

***201:22. Thermal processed fish products**
(CFTRI, Mysore—CSIR)

The products namely breaded and packed frozen fish curry are made from small bony fish into a snack food intended for house holds, restaurants and institutional feeding. The process involves thermal processing thereby softening the bones, improving the flavour and retaining cent per cent yield of dressed fish. The SEU is 500 kg of each product per day. The working capital required is Rs. 3.5 lakhs (1982), as this form only units of a fullfledged fish processing plant which will handle several frozen and canned fish products. Thus investment on plant and building and equipment have been excluded.

***201:23. Optimised milk food for infants**
(CFTRI, Mysore—CSIR)

The optimised milk food developed is unlike other commercial formulae which contains about 22% protein, the protein content of the infant food is only 12%, it also has an adequate level of essential fatty acid which can be easily digested by the babies. The level of protein and essential fatty acid of the product, when reconstituted with water, is similar to that of breast milk. Capacity for SEU for this process is 5 tonnes per day of two shifts.

201:24. Annatto crystalline dye
(CFTRI, Mysore—CSIR)

Annatto dye finds its use in dairy industry for colouring of butter, cheese and margarine. It is also used in ice-creams, bakery products and edible oils. Annatto dye is used by the cosmetic industry in products such as lipstick, suntan etc. It also finds application in drying of leather and floor wax ingredients. Capacity for SEU for this process is 1 tonne of annatto seeds per day of 8 hours shift. Investment involved in the plant and equipment is approximately Rs. 175 lakhs (1987).

Following processes are also available for licensing:

1. **Integrated processing of seasame seed**
   (CFTRI, Mysore—CSIR)

*2. **Spice oleoresins**
   (CFTRI, Mysore—CSIR)

*3. **Weaning foods**
   (CFTRI, Mysore—CSIR)

4. **Instant mango and lime pickle**
   (CFTRI, Mysore—CSIR)

DRUGS AND PHARMACEUTICALS INDUSTRY
CODE 300

***300:1. Theophylline, aminophylline and caffeine**
(NCL, Pune—CSIR)

Theophylline and aminophylline are used as myocardial stimulant, diuretic and as a drug for bronchial asthma. Caffeine is widely used as stimulant. The process developed envisages the use of dimethyl urea as the starting material for the manufacture of theophylline, aminophylline and caffeine. SEU for this industry is 60 tonnes per annum.

***300:2. 70% sorbitol from dextrose monohydrate**
(NCL, Pune—CSIR)

Sorbitol is an intermediate used in the manufacture of vitamin C. It is also used in cosmetic creams, tooth paste, tobacco, gelatin preparation and in textile and paper industries. Dextrose monohydrate is hydrogenated under pressure and sorbitol solution is decolorised and concentrated. Capital outlay for a plant of 300 tonnes capacity per year is estimated at Rs. 6 crores (1985).

***300:3. Vitamin B_6**
(NCL, Pune—CSIR)

Vitamin B_6 is an important drug used for certain types of anaemia, nausea and nervous disorders. It is also used in conjunction with other vitamins of B group. Starting from paraldehyde, dl-alanine is prepared which is converted to ethyl N-formylalaninate and to 4-methyl 5-ethoxy oxazole from which vitamin B_6 is prepared. SEU is 10 tonnes per annum.

***300:4. Diazepam**
(NCL, Pune—CSIR)

Diazepam is an important drug used as an anti-anxiety agent. Process consists of condensation of p-nitrochlorobenzene with benzyl cyanide. The intermediate compound is condensed with chloroacetyl chloride to give N-methyl-chloro acetamide which is converted to diazepam.

***300:5. P-nitrophenol**
(NCL, Pune—CSIR)

P-nitrophenol is used for the manufacture of parathion and para acetamol. The process consists of hydrolysing p-nitrochlorobenzene with caustic soda solution at elevated temperature. SEU for this industry is 300 tonnes of product per annum.

***300:6. Calcium gluconate**
(CECRI, Karaikudi—CSIR)

Calcium gluconate is extensively used for the treatment of calcium deficiency. The know-how for electrolytic oxidation of glucose to calcium gluconate developed at the institute is based on rotating anode whereas the conventional methods utilise stationary electrodes.

***300:7. Glyoxalic acid**
(CECRI, Karaikudi—CSIR)

Glyoxalic acid is a potential organic synthetic agent used in the manufacture of perfumery chemicals, pharmaceutical, dyes, etc. The production envisages the electro-chemical reduction of oxalic acid. The process has been studied on 100 amp cell producing 102 kg of acid per batch. Oxalic acid, sulphuric acid and calcium carbonate are the raw materials required. SEU for the industry is for the production of 30 tonnes of glyoxalic acid per annum.

***300:8. P-nitrobenzoic acid**
(CECRI, Karaikudi—CSIR)

Para-nitrobenzoic acid is mainly used in the preparation of para-aminobenzoic acid which is used as intermediate in pharmacological industry. The process envisages the production of para-nitrobenzoic acid by electro-chemical oxidation. SEU for this industry is 60 tonnes of p-nitrobenzoic acid per annum.

***300:9. Xanthotoxin from Heralceum candicans roots**
(RRL, Jammu—CSIR)

This is another process for producing xanthotoxin from Heralceum candicans roots. The roots are available in plenty in Jammu & Kashmir and Himachal Pradesh.

***300:10. Centimizone**
(CDRI, Lucknow—CSIR)

Centimizone is an anti-thyroid drug used for the treatment of thyrotoxicosis. This drug has been found to be effective in patients who have become resistant to other drugs like neomercazole. Present demand of the drug is estimated at 50 kg per year. Main raw materials are isopropyl alcohol, bromine, red phosphorous, ethylene diamine and carbon disulphide.

***300:11. Anti-epilepsy drug**
(CCRAS, New Delhi—Min. of Health & Family Welfare)

The Council has developed an anti-epilepsy drug based on Ayurvedic formulation using herbs and plants available indigenously. The drug has been found to be a cheap, tolerated and safe remedy for epilepsy. The clinical trials conducted on patients have proved that the drug is an effective chemoconvulsive agent capable of controlling fits without causing any side effects. Besides, in contract with the usual anti-epileptic materials, the drug improves the memory and the power of concentration of the patient.

***300:12. Niacinamide**
(CDRI, Lucknow—CSIR)

Niacinamide is an essential additive in all vitamin B-complex preparations. Demand is of order of 300 tonnes per year. The process is carried out in 2 stages (i) conversion of B picotinic to nicotinic acid, (ii) conversion of nicotinic acid to niacinamide.

***300:13. 8-hydroxy quinoline from quinoline**
(CDRI, Lucknow—CSIR)

8-hydroxy quinoline is an intermediate product for the manufacture of halogenated 8-hydroxy quinoline which is widely used for treatment of gastro intestinal infections of amoebic and bacterial origin. CC Rs. 25 lakhs for 30 tonnes per annum plant.

***300:14. Human chorionic gonadotrophin**
(Institute for Research in Reproduction, Bombay—ICMR)

HCG is used for in the preparation of regents for detection of normal pregnancy and ovulation, in the treatment of fertility in the human male and famale and in foetal salvage. The process developed is based on the use of human pregnancy urine.

300:15. Methaqualone and methaqualone hydrochloride
(RRL, Bhubaneswar—CSIR)

Methaqualone is an accepted non-barbitrate sedative already in medicinal use. The process has been studied on 1 kg batch scale. Isatoic anhydride, anthranilic acid, acetic anhydride, O-toluidine and hydrochloric acid are the main raw materials required. SEU for the industry is for the production of 500 kg each of methaqualone and methaqualone hydrochloride and 1,200 kg of acetic acid per year.

300:16. Heavy basic magnesium carbonate
(CSMCRI, Bhavnagar—CSIR)

Heavy magnesium carbonate is used in medicine as an antacid and laxative. The process consists in heating solution of sodium carbonate and magnesium chloride. Suggested economic unit for this industry is 30 tonnes of heavy basic magnesium carbonate per annum. It is estimated that the plant will cost Rs. 5.16 lakhs (1977).

300:17. Diagnostic reagent absorbent strips for testing ketonic bodies in urine
(DRDE, Gwalior—DRDO)

The conventional method for testing ketonic bodies in urine takes time and is cumbersome. The strips developed by the laboratory have been found to be sensitive up to 0.01% of acetone. CC Rs. 2 lakhs (1984).

300:18. Quinapyramine sulphate chloride (QSC—veterinary drug)
(NCL, Pune—CSIR)

Quinapyramine sulphate/chloride (QSC veterinary drug) is a remedial drug of choice for combating trypanosomiasia fatal disease caused by the organism trypanosoma. It is a life saving drug for animals, acts as curative as well as prophylatic. The process involves three steps, the starting material being p-aminoacetanilide.

300:19. Beta-phenylethylamine
(RRL, Hyderabad—CSIR)

Beta-phenylethylamine is widely used by pharmaceutical concerns in the formulation of chloroform, in the development of colour photography and in the manufacture of N-B-phenylethyl anthranilic acid (RH-8). The process is based on catalytic pressure hydrogenation of benzyl cyanide in presence of methanolic ammonia in an autoclave. The estimated demand would be about 30 tonnes per year. The work has been carried out at 7 kg per batch scale. Process is available on 'as is basis'.

***300:20. Anti-malarial drug**
(CCRAS, New Delhi—Min. of Health & Family Welfare)

The Council has developed an anti-malarial drug based on Ayurvedic formulations, using abundantly available indigenous herbs and plants. Extensive field trials and clinical studies have been conducted on malaria patients. The efficacy of the drug was found to be as good as that of standard allopathic drugs being used to control malaria. The drug has also been found effective against micro-filaria and amoebic infections. In addition, the Ayurvedic drug is cheap and nontoxic.

300:21. High absorbent surgical dressings
(SRI, Delhi—Funded by ICMR)

High absorbent surgical dressings can be used in dressing of wounds in general and in surgery and burn cases in particular. The dressings developed at SRI are the substitute to the indigenously made absorbent material with improved properties.

300:22. Calcium lactobionate
(CECRI, Karaikudi—CSIR)

Calcium lactobionate is an important drug intermediate used for the preparation of calcium tablets and injectables. The process developed at CECRI envisages the electrolytic oxidation of lactose mono hydrate solution in sodium bromide to calcium lactobionate. SEU for the production of 15 TPA of calcium lactobionate is estimated to cost Rs. 16.75 lakhs (1984).

***300:23. New cervical dilator (Isaptent)**
(CDRI, Lucknow—CSIR)

The device is used as an aid for termination of pregnancy and gynaecological operations. It is a substitute for an imported item named 'laminaria tent'. Nearly 4 lakhs cervical dilators are likely to be required every year in our country.

Following processes are also available for licensing:

1. **Beta-phenylethylamine**
   (CECRI, Karaikudi—CSIR)
2. **Benzylamine**
   (CECRI, Karaikudi—CSIR)

LEATHER INDUSTRY

CODE 400

***400:1. Binder RS acrylic resin emulsion as binder**
(CLRI, Madras—CSIR)

Acrylic resin emulsion is a very important chemical for leather auxiliary manufacturer as the same is used as a binder in finished leather manufacture. SEU 500 kg/day (2 shift operations).

***400:2. Cenlesols, 1, 2, 12, 30**
(CLRI, Madras—CSIR)

Cenlesols are a series of newer anionic fat liquors which relate to improvements in the manufacture of fat liquors with neutral oils. The cenlesols find very useful applications for chrome retained, side uppers softie nappas, lining leathers with good penetration on leather due to their greater stability to hard water, acidity and tanning materials. SEU is 120 tonnes/year for each product.

***400:3. Lacquer CA**
(CLRI, Madras—CSIR)

'Lacquer CA' is used for top coat finishes for leather. The technique developed is simple and does not involve complicate unit operations. SEU is 150 kg/shift.

***400:4. Sulphited oil fat liquor**
(CLRI, Madras—CSIR)

Fat liquors from marine oil using the sulphitation process have versatile application suitable for vegetable tanned, chrome retanned upper leather and light leathers. Capital required is Rs. 1.4 lakhs. Minimum economic plant size is 15 tonnes/yr. This oil is a good substitute for imported oils.

***400:5. Antifungal tablets**
(CLRI, Madras—CSIR)

Finished leather goods, foot wear and other leather articles which have great export potential get attacked by fungus, on leather goods can be prevented by using the antifungal tablets. The process is extremely simple and consists of mixing three compounds. The SEU is 50-100 kg/day plant. Total capital investment on plant and equipment is only Rs.10,000 (1986).

400:6. Urethane varnish based on castor oil

(CLRI, Madras—CSIR)

To get good shine and superior gloss on leather goods, this varnish is ideal. The varnish also gives protection to leather and gives highly water resistant, smooth and polishable finished surface. 25 tonnes of this varnish is required every year and the capital investment will be Rs.1.65 lakhs. No import of raw material is required.

***400:7. Syntans**

(CLRI, Madras—CSIR)

Synthetic tanning materials generally known is syntans are used in a number of operations in leather industry like pickling agent, bleaching of vegetable tanned leather, pre-tanning for vegetable leathers, bleaching of E.I. skins, reduction of sludge in the tanning pits, imparting fullness to leathers. SEU would be a plant having a capacity of 500 tonnes per annum (single shift).

***400:8. Casprol-T**

(CLRI, Madras—CSIR)

Casprol-T is a very important textile auxiliary. It is made from chrome shavings of leather industry. SEU is 800 kg per day (2 shift operation). Total capital investment on plant and machinery is about Rs.2 lakhs (1986).

Following process from CLRI is also available for licensing:

1. **Modified tanning extract**

METALLURGY INDUSTRY

CODE 500

***500:1. Recovery of zinc metal from galvanizer's dross by atmospheric distillation**

(NML, Jamshedpur—CSIR)

The know-how developed at the National Metallurgical Laboratory involves a process of distilling the zinc from dross under atmospheric pressure. The total capital investment for a plant having a capacity of 6,000 TPA (3 shifts operation per day) is estimated to be Rs. 8 lakhs.

***500:2. Extra fine zinc dust**

(NML, Jamshedpur—CSIR)

Distilled zinc dust is very fine zinc powder with up to 98% mesh size below 45 microns. Its main use is in the sodium hydrosulphite industry. The estimated cost of the plant having capacity of 1,000 tonnes per annum, is Rs.1 crore.

***500:3. Electrolytic manganese metal**

(NML, Jamshedpur—CSIR)

Electrolytic manganese metal has a high degree of purity and is suitable as a manganese additive for the manufacture of ferrous and non-ferrous alloys. The process has been developed for the production of electrolytic manganese metal of 99.95% purity from low grade manganese ore. The ore is first reduced then leached in the spent liquor that comes out of the electrolytic cells. The leached solution is purified for removal of impurities. Then it is electrolysed to give pure manganese metal. CC for 1,000 tonnes EMM per year, production will be about Rs.7.5 crores.

***500:4. Dental amalgam alloy**

(NML, Jamshedpur—CSIR)

The product in the amalgamated condition is used for filling up the cavity of the decayed teeth. The raw material in the purest form are melted in a furnace. Melt is stirred thoroughly before pouring. Pouring. is done in mould. The ingot is then homogenised, processed for obtaining proper particle size followed by suitable heat-treatment. Successful clinical service trial was conducted at Tata Main Hospital.

*500:5. Silicon nitride
(CGCRI, Calcutta—CSIR)

Silicon nitride is a synthetic non-oxide refractory material for use in special application. The silicon nitride ceramics have got outstanding thermal shock resistance, high strength at high temperature, extreme resistance to corrosion of all non-ferrous metals. CC for 5 tonnes per annum capacity plant is Rs.9 lakhs.

*500:6. Air and nitrogen atomised extra fine non-ferrous metal powders
(NML, Jamshedpur—CSIR)

The straight non-ferrous metal powders are made by the process of atomisation, wherein a stream of molten pre-alloyed metal is atomized by a stream of pressurized fluid under properly controlled conditions to yield the desired mesh sizes, sieve analysis, particle shape and other required physical properties.

*500:7. Electrical resistance alloys for heating elements
(NML, Jamshedpur—CSIR)

The electrical heating elements developed are free from non-indigenous nickel and cobalt.

500:8. Treatment of waste metallic fines for metallic recovery
(NML, Jamshedpur—CSIR)

During the process of melting, casting, machining, powder making and various other operations metal losses do occur in the form of dross fines. swarfs etc. The process worked out is for the recovery of metal from various metallic fines. The process is simple and does not involve any complicated machinery. SEU for this industry is for treating 100 to 250 kg of samples per batch.

500:9. Improved process for smelting of lead
(NML, Jamshedpur—CSIR)

The principal of the process is metallotheramic. Lead concentrate is mixed with cheaply available metallic reductant and appropriate fluxes and ground, made into pellets, and smelted, when lead separates as metal in molten condition. Lead is cast into ingot moulds. The purity of the metal obtained by this process is upto 99.5% Pb.

500:10. Wear & abrasion resistant cast iron "NML-Wearnot"
(NML, Jamshedpur—CSIR)

"NML-Wearnot" cast iron has been developed from indigenous raw materials. Such cast irons in different case shapes, from basic components for various machines, such as sand slingers, centrifugal shot blasting machines which are used in foundries, Ally cast irons commonly used for these purposes contain nickel and/or molybdenum in addition to chromium which is present in all cases. Since the sources of nickel and molybdenum are scarce in India, NML, Jamshedpur, has developed "NML-Wearnot" cast iron containing no nickel and molybdenum.

Financial details can be worked out based on the unit proposed to be set up.

*500:11. Electrolytic iron powder
(RRL, Bhubaneswar—CSIR)

High purity powder is used in chemical industries as a catalyst, automobile industries, welding electrodes etc. The process developed at RRL, Bhubaneswar, consists in the conversion of acid free iron chloride into ferrous chloride. The ferrous chloride is used as a catholyte and saturated solution of sodium chloride is used as anolyte. The anode and cathode chambers are separated by using a suitable porous diaphragm. Stainless steel sheets and graphite are used as cathode and anode respectively. The deposited iron is removed in the form of brittle flakes which are subsequently ground to the desired size. The process has been studied on bench scale and 200 gm of iron powder per day has been produceed. Suggested economic unit for this industry is for the production of 30 tonnes of iron powder per annum.

500:12. High purity graphite

(RRL, Bhubaneswar—CSIR)

High purity graphite finds application in special grade electrodes and brushes, lubricants, sintered product, explosives, unclear field etc. Graphite powder (90-96%), hydrochloric acid, the hydrofluoric acid and sodium chloride are main raw materials required. SEU for this industry is 250 tonnes of 90% graphite per annum.

500:13. Beneficiation of graphite

(RRL, Bhubaneswar—CSIR)

Graphite in its pure form is employed in the production of various articles such as crucibles, etc. The know-how gives 96 to 98% of pure graphite per annum. Estimated capital outlay is Rs. 2.62 lakhs.

500:14. Chromate treatment of zinc and die-cast zinc alloy

(CECRI, Karaikudi—CSIR)

Zinc and die-cast zinc alloy such as automobile parts and others like gas regulators, carburettor parts are required to get chromate film for corrosion protection with pleasing decorative appearance. The process developed by CECRI is very simple and involves the treatment of automobile parts after degreasing and pickling at a temperature of 30-35°C for a duration of 20-60 sec. A large scale trial was carried out with a carburettor firm in Madras and they were satisfied with the treatment. Suggested economic unit for this industry is for the production of 3 tonnes of the product per annum.

500:15. Copper plating of stainless steel

(CECRI, Karaikudi—CSIR)

The stainless steel utensils are poor thermal conductors of heat and an appreciable amount of heat is lost by radiation. These drawbacks can easily be eliminated, if the surface coming directly into contact with flame or hot plate is plated with copper of thickness 0.02″.

CECRI's process envisages the direct plating of copper on stainless steel from an acid copper chloride bath being a strike bath followed by a copper build up from conventional acid copper sulphate bath.

*500:16. Zinc powder by direct reduction of zinc oxide/hydroxide/carbonate

(CECRI, Karaikudi—CSIR)

Zinc powder is extensively used in paints. It has other applications also. In India, the natural resources of zinc are lean and are not sufficient to meet the demand of the country. An electrolytic process for the reduction of zinc compounds, the oxide and hydroxide in particular, has been developed by the laboratory. Zinc compounds are the by-product of paint industry, galvanising industry and chemical industry.

*500:17. Aluminium alloy anodes for cathodic protection

(CECRI, Karaikudi—CSIR)

Aluminium alloy anodes are used for the cathodic protection of steel structures in sea water and also seagoing vessels. At present cathodic protection is on limited scale, although the need for such a protection is being realised by the Naval and port authorities. With the adoption of such a protection the estimated demand of aluminium alloy anodes is expected to be 1,000 tonnes per annum. CECRI has developed a suitable alloy of aluminum, zinc and mercury for cathodic protection. The new process envisages the melting of aluminium and the alloy ingredients suitable proportions. The equipment required for the process is indigenously available and with the exception of mercury other raw materials are also indigenously available.

*500:18. Zinc metal from by-product zinc compounds

(CECRI, Karaikudi—CSIR)

Considerable amount of zinc metal is lost as skimming and dross during galvanising of this iron tubes. India cannot afford to throw away in the electrolysis of a suspension of finally divided waste in an alkaline solution between an iron anode and a stainless steel cathode. Zinc is either obtained in the form of powder of sheet by suitably adjusting the conditions. SEU for this industry is 250 kg zinc per day.

*500:19. Foundry core binder (Sinol core binder)

(NCL, Pune—CSIR)

Foundry core binder is specifically used in steel foundries for high dimensional accuracy and finish to moulded parts. Foundry core binder is prepared by the polymerisation of cashewnut shell liquid. SEU is one tonne per day.

*500:20. Electrolytic manganese dioxide

(CECRI, Karaikudi—CSIR)

Electrolytic manganese dioxide (EMD) is used in the manufacture of dry cells. CECRI has successfully developed a process for the manufacture of EMD with chloride bath. The quality of the product has been tested to be uniform and satisfies all the stringent specifications prescribed for electrolytic grade manganese dioxide. SEU for this industry is 1,000 tonnes EMD per annum.

*500:21. Shatter alloy components

(DMRL, Hyderabad—DRDO)

Shatter alloy is an aluminium based alloy with its chief characteristic of shattering into small fragments or a clean hole made through when hit by a bullet.

500:22. Recovery of vanadium pentoxide from vanadium sludge of alumina industry

(NML, Jamshedpur—CSIR)

Vanadium is an important metal which finds extensive uses in the form of metal, oxides and alloys. Vanadium pentoxide is used mostly as catalyst in sulphuric acid manufacture, for the production of ferro-vanadium and titanium vanadium-aluminium alloy and other vanadium compounds.

Vanadium pentoxide produced has been compared with imported V_2O_5 of equivalent specification and found to be equally good. V_2O_5 has been found conforming to the refined grade.

500:23. Dense carbon aggregate and paste

(NML, Jamshedpur—CSIR)

The material namely dense carbon aggregate can be used for carbon products like electrodes, soderberg paste, cathode lining, carbon refractories, tubes and blocks. The dense carbon aggregate with its low-ash content and good strength as well as electrical and physical properties possesses almost all the requisite characteristics for use as a raw material in place of imported anthracite.

The process as worked out briefly consists of the unit process employed in traditional carbon industries. Basic ingredients are reduced to a specific fineness, conditioned with a binder, briquetted and then heat-treated according to a specified schedule at a maximum temperature which varies with the nature of basic materials employed. The heat-treated briquettes are then crushed and graded as per the needs of the consuming industry and the product thus obtained is called dense carbon aggregate.

500:24. Iron-silicon magnesium alloy

(NML, Jamshedpur—CSIR)

For the manufacture of nodular iron, several nodularising agents are used, the most common amongst them is the nickel, magnesium alloy. Due to very limited indigenous availability of nickel, the use of iron-silicon magnesium alloy has an increasing scope of its utilisation.

The alloy is made by introducing magnesium metal and misch metal in molten ferrosilicon. The resultant Fe-Si-Mg alloy is cast into metallic moulds and allowed to solidify.

Little capital investment is needed on the equipment as it can be manufactured in an existing plant.

500:25. Magnesium based inoculant briquettes for nodular cast iron

(NML, Jamshedpur—CSIR)

The process deals with the production of briquettes, consists mainly of cast iron or steel turning, sponge iron and magensium chips of appropriate sizes with addition of other chemicals and ferro alloys. The briquette material of suitable sizes are mixed throughly before pressing so that uniform distribution of ingredients is obtained.

The cost of the briquette by the above process is comparatively cheaper than conventional alloys at present used for the production of nodular cast iron. Better recovery of magnesium can be obtained by suitably controlling the bulk density.

*500:26. Aluminium base sacrificial anode for cathodic protection

(NML, Jamshedpur—CSIR)

It is an aluminium alloy and contains upto a maximum of 5% alloying elements. The alloy in a cast condition has excellent driving voltage and no tendency to get polarized.

It is used for the protection from corrosion of ship hull, underground pipe line heat exchanger tubes, harbour installations etc.

The alloy can be commercially prepared in aluminium foundry without requiring any special equipment or arrangement. Once cast the material is ready for the use as galvanic anode in service.

Little capital investment is needed if the melting and casting facilities are available with the existing plant.

500:27. Vinyl coated steel and aluminium

(NML, Jamshedpur—CSIR)

The coated steel and aluminium can be utilized in instrument and equipment casing, electrical panneling and ducting, panneling in coaches and buses etc.

The know-how developed for production of vinyl coated steel and aluminium sheets involves a process comprising of (i) pretreatment of steel/aluminium sheets, (ii) production of chemical coating such as phosphating or chromating, (iii) application of a primer followed by baking, and (iv) application of a finish coat folllowed by baking at appropriate temperature.

A small scale industrial unit capable of producing 12,000 sheets of 1 sq. metre unit area per year based on 2 shift operations a day and 300 working days in a year is estimated to cost Rs. 6.25 lakhs.

500:28. Copper clad aluminium sheet and strip

(NML, Jamshedpur—CSIR)

Copper clad aluminium sheet has good electrical and thermal property as well as light weight and good solderability. This clad metal can be used to replace copper in a number of conventional uses leading to conservation of copper. The other uses of clad metal are halftone printing plates, decorative tiles and trips, pots and pans, costume jewellery, badges, radiating fins etc.

Copper clad aluminium sheet is produced by cold roll bonding of copper sheet with aluminium sheet. Adequate surface preparation is essential before roll bonding is done.

*500:29. Nickel magnesium alloy

(NML, Jamshedpur—CSIR)

The process developed at NML, Jamshedpur, envisages the production of alloy by alloying nickel, magnesium and misch metal. The molten alloy is cast at the appropriate temperature into steps or any shape in metallic moulds. When solidified it can be stored and is ready for use.

Little capital investment is needed if the melting equipment is available with the existing unit.

500:30. Semi-automatic carbon analyser

(NML, Jamshedpur—CSIR)

Semi-automatic carbon analyser is an apparatus for the estimated of carbon in steel, alloy steel, cast iron, pig iron, etc. This apparatus functions on the same principle as the conventional carbon apparatus (Strohlein type), but incorporates special design features to reduce the operational difficulty and even a skilled technician can operate it. The analyser can be attached to silicon carbide tubular furnace and can be manufactured by small scale industries with usual glass blowing all light engineering facilities.

500:31. Reactive NML filters for aluminium and its alloys

(NML, Jamshedpur—CSIR)

Aluminium and its alloys are always associated with dissolved hydrogen, oxide and dross inclusion which deteriorate their mechanical properties, workability and service performance. In order to improve the cleanliness of the melt, National Metallurgical Laboratory has developed certain reactive filters which have been successfully tried on commercial scale. The salient features of the filter media are (i) high yield of good quality product i.e. better surface finish, low inclusion and dissolved gas content, (ii) reduction of sodium level in the filtered material, and (iii) grain refining of the filtered material.

500:32. Sacrificial aluminium alloy anodes for cathodic protection of ships and steels structures

(NCML, Bombay—DRDO)

The products are used for protection of steel structures continuously submerged in sea water against corrosion. The structures include stationary and floating structures such as ships, oil drilling rigs, offshore platforms, wharf walls, dockgates, etc. Presently the floating structures are protected with galvanic aluminium anode system.

500:33. Magnesium alloy anodes for cathodic protection

(CECRI, Karaikudi—CSIR)

Magnesium alloy anodes are used as galvanic anodes in cathodic protection of structures and equipment. The new process involves the melting and then casting of magnesium and other constituents of the alloy with anodes.

*500:34. Electrolytic chromium

(CECRI, Karaikudi—CSIR)

Chromium powder is used for the preparation of special type of welding electrodes. The process broadly consists in depositing chromium in the form of brittle sheets from chromic acid containing known amount of sulphate ions. SEU for the industry is for the production 22.5 tonnes of chromium per annum. The total investment is estimated at Rs.26 lakhs.

500:35. Electrolytic preparation of iron powder

(CECRI, Karaikudi—CSIR)

Electrolytic iron powder finds extensive application as reductant in the manufacture of sintered compacts and welding electrodes and also for special flame cutting operations. The process consists in electrolysis of ferrous chloride solution using mild steel anode and stainless steel cathodes.

500:36. High strength low alloy structural steel designated MA-602

(NML, Jamshedpur—CSIR)

High strength low alloy structural steel has been developed by NML, Jamshedpur and named as MA-602 which can be used in construction of ships, bridges, buildings, pressure vessels, etc. The demand of the alloy is good and estimated to increase to 50,000 tonnes in 1984-85. A separate plant for this alloy is not advisable. A mini steel plant can be utilised for the production of the alloy.

500:37. Inoculants designated as NML-PM 122 for aluminium/aluminium alloys (in the wire form)

(NML, Jamshedpur—CSIR)

An inoculant in the wire form has been developed for aluminium/aluminium alloys. The practice of inoculation in aluminium and its alloy melts is to achieve grain refinement and hence to obtain cast structure with uniform finer grain size. The finer grain size enhances the thermo-chemical properties, reduces the risk of tearing, cracking into mould etc. The demand has been estimated as 400 tonnes of conventional inoculants. Its production can be taken up by units having facilities for melting and wire drawing of aluminium and its alloys by putting up additional melting and annealing furnaces.

500:39. NML-PM6 welding filler wires/rods

(NML, Jamshedpur—CSIR)

Sound and defect free welding of high strength aluminium alloys with the welded region possessing adequate mechanical properties comparable with those of the patent metal, is an important aspect of the technology of fabrication of aluminium alloys for constructional purposes and is achieved through the use of filler wire/rod of specific composition. Although the nominal composition of the filler wire is described in the various national standards, their production technology required development to suit indigenous resources.

NML, Jamshedpur, has developed melting, solidification and processing technology of medium strength filler wire-PM6 and conducted industrial trials to confirm its suitability for welding high strength aluminium alloys. The strength of weld metal is around 28 kg/mm^2 (as welded condition).

Plants with facilities like melting, casting, extrusion and wire drawing can take up this technology as a diversification without any major additional equipment.

*500:39. Method of making cupric (Cu) silver (Ag) and chloride (Cl) ion sensitive electrodes

(CECRI, Karaikudi—CSIR)

Ion sensitive electrodes are used as electro-analytical probes for ionic concentration measurements in solution. The electrodes have a wide range of applications. The process developed at CECRI consists in preparing non-porous membrane discs of suitable diameter and thickness from the active materials containing silver sulphide or a composite of sulphide or silver chloride. The composites are precipitated from their soluble salts, the compressed under vacuum and the resulting membrane are assembled to electrodes. SEU for this industry is production of 1,500 electrodes per year.

500:40. Chromised steel

(IIT, Bombay)

Chromising process consists depositing chromium on an article made of steel or any other suitable material or alloy from a vapourised or a liquified chromium halide at a temperature of 1000 to 1100°C.

The product thus produced can be used as gas cooking and furnace parts, flue and exhaust pipes, heat exchangers, castings, forging, etc. It can also be used as corrosion resistance material for automotive mufflers parts, fuel tanks, for laundry machines, textile machinery, etc. It can also be used wear resistance material for transmission chain rolls (made from mild steel and then chromised), chromised tools like files, taps, dies, fuel injection plates, etc. SEU is 0.3 tonne of substrate metal i.e. 25,000 sq. cm. of chromising area per day of 3 shifts.

The capital investment required for the plant and equipment is estimated at Rs.8.5 lakhs, excluding the cost of land and building and working capital is Rs.4 lakhs.

500:41. Clay graphite stopper heads viz. 'NML Flovel-35' & 'NML Flovel-50'

(NML, Jamshedpur—CSIR)

Clay graphite stopper heads are used for controlling the flow of molten steel during teeming process through nozzles fitted at the bottom of ladle. These give better performance than fire clay stopper heads under stringent service conditions. Demand is expected to be 300 tonnes per annum. SEU is 200 tonnes per annum and capital outlay is Rs.36 lakhs.

500:42. Synthetic cryolite

(NML, Jamshedpur—CSIR)

Cryolite is one of the essential minerals for aluminium industry. It is chiefly used as fused bath for the reduction of alumina in the aluminium production cell.

500:43. Graphite aluminium composite

(RRL, Bhopal—CSIR)

Graphite aluminium composite (GRAL) is a new inexpensive antifriction material with very high potential for tribological applications. It can be used for making pistons, cylinder liners, bearings, bushes, casings, wear plates, pump impellers, etc.

The know-how developed consisting of dispensing graphite particles in the aluminium alloy matrix by simple foundry metallurgy techniques. The composites thus produced are cast in different shapes and sizes. A unit to produce 90 TPA of composite materials requires an investment of Rs.5 lakhs towards the plant and machinery (1986).

500:44. High alumina cements by new technique of sintering

(CGCRI, Calcutta—CSIR)

High alumina refractory cement with alumina ranging from 45-50%, 65-66% and 72-78% are suitable for making high quality high alumina castables for application at temperatures ranging from 1300° to 1800° C. The Institute has developed a new sintering technique for the production of high alumina cement from bauxite/technical or hydrated alumina and limestone or calcite at a lower temperature of sintering i.e. 1300-1500° C. The capital investment for a plant of capacity 1000 MT/year is Rs.72 lakhs.

500:45. Synthetic high alumina aggregates

(CGCRI, Calcutta—CSIR)

The Institute has developed a new process for producing high alumina aggregates (54-86% Al_2O_3) that minimises the use of sintering temperatures and the overall cost of production.

High alumina aggregates produced by this process are suitable for making high quality refractory bricks, shapes and minolithics for applications in the vulnerable region of iron and steel, cement, chemical and other industries where high temperature and corrosive atmosphere are involved.

The total capital investment for a plant of capacity 5000 TPA.

*500:46. Electrolytic manganese dioxide

(NML, Jamshedpur—CSIR)

Electrolytic manganese dioxide is used chiefly in battery and dry cell industry. The process developed at NML, Jamshedpur, involves the production of acidic manganese sulphate solution from manganese ore and electrolysing it to yield manganese dioxide.

500:47. Weather resistant, smokeless, hard and moulded fuels for domestic and/or industrial purposes

(CFRI, Jealgora—CSIR)

The process consists of crushing raw materials (cokebreeze, devolatilised coal or smokeless coal) to finer sizes, mixing the same with bituminous binders such as tar/pitch etc., in requisite proportions, briquetting the mixture to a moulded shape or form. Except twinpaddle press, rest of the equipment are available indigenously. The estimated capital investment for a plant producing 36,000 tonnes per annum (3 shifts operation) varies between Rs.60 lakhs depending on the nature of fuel used.

*500:48. Pelletised coke

(CFRI, Jealgora—CSIR)

CFRI has developed a process for the production of agglomerates from middlings or rejects of coking coal washeries and low grade coking coal for domestic, industrial and metallurgical fields. The estimated capital investment for a plant having a production capacity of 100 tonnes per day is Rs.75 lakhs.

*500:49. Improved graphite crucibles

(NML, Jamshedpur—CSIR)

Graphic crucibles are widely used for melting brass and other non-ferrous alloy in iron and steel foundries. National Metallurgical Laboratory, Jamshedpur has developed process for the manufacture of clay bonded and carbon bonded crucibles.

500:50 Stainless steel powder

(NML, Jamshedpur—CSIR)

Stainless steel powder is made from stainless steel scraps. It is used in automobile industries. NML process is a chemical process and is not based on atomisation. Yield obtained is 95-96%. 100kg/day unit can be installed initially with provision of expansion with an investment of Rs.18 lakhs approximately (1987).

Following processes from NML are also available for licensing:

1. **Ferro-vanadium/vanadium rich slag from titaniferrous ores**
2. **Grain size control in aluminium and aluminium alloy castings**
3. **Aluminium alloy NML-PM53**

BUILDING AND CONSTRUCTION INDUSTRY

CODE 600

***600:1. Lime sludge based masonry cement**
(CBR!, Roorkee—CSIR)

The developed masonry cement is made by intergrinding waste lime sludge with portland cement and a small amount or air entraining agent is also added if required. SEU 4,800 tonnes per annum. CC Rs.2 lakhs.

***600:2. In-situ flooring composition for railway coaches**
(CBRI, Roorkee—CSIR)

Magnesium oxychloride cement based flooring composition being resilient and light is used as flooring material for railway passenger coaches. Some new formulation based on calcined magnesite as well as partially calcined dolomite have been developed by Central Building Research Institute, Roorkee. The new formulation costs less. Estimated capital outlay for this industry is Rs.8.4 lakhs for 3000 tonnes per annum (1986).

***600:3. New formulation of an acid resistant cement**
(CBRI, Roorkee—CSIR)

With the development of chemical fertiliser and allied industries, demand for construction materials resistant to various chemicals in increasing. Sodium based products are already in use. A new formulation based on sodium composition has been developed at CBRI. The new composition conforms to IS:4832(69). The cost of production comes to Rs.7,500 per tonne, ex-works (1987).

***600:4. Improved method of constructing compaction pile**
(CBRI, Roorkee—CSIR)

Know-how for the process of constructing bored piles in loose sandy soils when the compaction in concrete as well as compaction of soil around the base is effected simultaneously by drying reinforcement through freshly laid concrete. These piles are particularly useful in location with high water table where cement concrete with high water cement ratio has to be placed through a tremie pipe and any compaction of concrete or soil around is not possible by normal means. An economy of about 20% can be achieved on the cost of formulation.

***600:5. Acid and alkali resistant tiles**
(CBRI, Roorkee—CSIR)

The various chemicals widely used in fertiliser and other chemical industries extensively damage the flooring. Bitumen is considered to be suitable for such flooring but the filler materials used in it are not resistant to acid. The Institute has developed recently a chemical resistant tile, which is strong as well as resistant to acids and alkalies. Suitable adhesive for joining the tiles has also been developed.

The estimated capital investment for a plant producing 2,000 numbers of tiles of size 15 cm+15 cm+1 cm per day is Rs. 3 lakhs. The cost of production is about Rs.8 per tile (1987).

***600:6. Improved burning of limestone**
(CBRI, Roorkee—CSIR)

Lime burning is mostly practical in India in country type rectangular 'bhattis'. These are not only highly heat wasteful but the lime produced is also not of uniform quality. It is also not possible to burn limestone in these bhattis under strict controls.

A design of a kiln having a high thermal efficiency has been developed at the Institute.

The cost of the construction of a kiln with a burning capacity of 10 tonnes of limestone per day is estimated to be about Rs.3.6.lakhs (1985).

600:7. Cement coconut shell pith concrete
(CBRI, Roorkee—CSIR)

A thermal insulating material 'Cement coconut shell pith concrete' based on coconut pith which is available abundantly, has been developed successfully. It can be compared to the conventional insulating materials. The cement coconut pith concrete is much lighter, easier to apply and gives better thermal insulation for equal cost.

*600:8. Wood wool boards

(CBRI, Roorkee—CSIR)

Wood wool boards made of wood wool, portland or magnesium oxychloride cement. Wood wool is a material made from wood fibre. It is primarily used as a thermal and acoustic insulation material. It has good flexural properties and can be used as a structural panel material. It has resistance to propagation of fire and termite attack. Its surface can be plastered.

The estimated cost of production of 75,000 boards of size 2 m+ 0.5 m+ 25 mm is Rs.17 lakhs (1985).

*600:9. Lime hydrator

(CBRI, Roorkee—CSIR)

The Institute has developed a machine for the manufacture of hydrated lime. It is a sturdy machine and occupies less space. It has three tiers having well defined functions. The steam generated during the process of hydration is utilized for pre-heating the incoming water. This results in the acceleration of the process of hydration. The estimated capital investment for a plant of production capacity of about 2,000 TPA is Rs. 12 lakhs and cost of production is about Rs. 621 per tonne (1985).

*600:10. Rapid setting lime plaster

(CBRI, Roorkee—CSIR)

The lime plaster developed by the institute starts setting in about two hours and becomes fairly hard in about 24 hours and develops adequate strength in 28 days. The plaster can be mixed with two to three of sand before application. A single coat of this plaster is sufficient and two coats are applied if better finish is desired.

*600:11. Plastic masonry paint

(CBRI, Roorkee—CSIR)

The paint developed is easy to prepare and apply. It is free from odour. It possesses excellent washability and scrub resistance and is specially suitable for new surfaces because of its high alkali resistance properties. It can also be satisfactorily applied on exterior surfaces with a few other activities.

*600:12. General purpose and heavy duty flooring tiles from magnesium oxychloride cement

(CBRI, Roorkee—CSIR)

These tiles require only 2 days curing as against 15 days for portland cement concrete tile. These can be made ready for use within about a week of their manufacture and possess higher transverse strength and resistance to abrasion than portland cement concrete tiles.

These are better resistant to fire and attack from grease, oil, milk, paints, petroleum products etc., have low thermal conductivity and also possess antiseptic properties.

*600:13. Partially calcined dolomite for use in magnesium oxychloride cement compositions

(CBRI, Roorkee—CSIR)

The method of peparation is simple and does not require any complicated plant and machinery. Partially calcined dolomite based magnesium oxychloride cement compositions conform to Indian Standard specifications.

The compositions made from this material can be used for making precast flooring tiles, slabs, wood wool boards, etc. in the same manner as the magnesite based compositions are used.

600:14. Impermeable cut off walls—thin

(CBRI, Roorkee—CSIR)

This is a semi-mechanised process of constructing thin and impermeable diaphragm walls in the ground. The technology provides a speedy method of construction in sandy and silty soils. It replaces the cumbersome, time consuming and uneconomic method of constructing steel pile cut off walls. All the machinery required in the process is indigenous.

600:15. Improvement of strength of asbestos cement products from blends of chrysolite and amphibole fibres and normal portland cement

(CBRI, Roorkee—CSIR)

In this process fiberisation and blending of fibre are to be carried out in a machine developed at CBRI. The process has been worked in the laboratory on hand moulded 25 cm × 25 cm size sheets.

The entire asbestos cement industry can use this process to improve the strength of A.C. products using amphibole fibres as a parts replacement of imported chrysolites. The fiberising machine used in this process is indigenously available and the expected cost of the machine is Rs.5,000 (1987).

*600:16. Design of a kettle for the manufacture of gypsum plaster or plaster of Paris

(CBRI, Roorkee—CSIR)

Uniform heating of gypsum can be carried out by using this kettle. All the raw materials are available in plenty in Rajasthan and the equipment can be fabricated indigenously. The calcined plaster complies with the Australian Standard Specification.

The estimated capital investment of a plant for producing 480 metric tonnes of plaster of Paris per annum with 300 working days based on two shifts operation a day, is Rs.2.4 lakhs. The cost of production is estimated to be Rs.540 per tonne (1987).

600:17. Sintered flyash aggregate

(CBRI, Roorkee—CSIR)

The light-weight concretes prepared with this type of aggregate possess 28 days compressive strengths up to 350 kg/cm^2 depending upon the mix. These light-weight aggregates can be used for in-situ concrete work, for the manufacture of load or non-load bearing masonry blocks and other precast concrete units such as roof and floor slabs. The estimated capital investment of a plant for producing 9,000 tonnes of sintered flyash aggregates per annum with 300 working days based on 3 shifts operation a day is Rs.18 lakhs (1987).

600:18. Building bricks from alumina red mud

(CBRI, Roorkee—CSIR)

There is always a large demand for building in the country. As the use of red mud does not alter the physical properties of the bricks, these can be used for all types of construction.

600:19. Coating for corrosion prevention in reinforced cement concrete construction

(CBRI, Roorkee—CSIR)

A suitable surface coating material based on portlant cement, sand and asphalt, or coal tar pitch for concrete surface has been developed by CECRI. The new coating can be advantageously employed wherever water proofing material are presently used to obtain additional protection to steel reinforcement inside the concrete. The cost of production has been worked out to be Rs.5.30 per sq. m.

*600:20. Clay pozzolana (surkhi) by fluidised bed calciner

(NBO, New Delhi and SRI, Delhi)

Surkhi is very common pozzolana and can replace cement to some extent. Conventional methods of production of surkhi give rise to high cost mainly due to their poor thermal effieciency. A continuous counter current fluidised bed calciner based on modified technique of fluidisation has been successfully developed. SEU for this industry is 45,000 tonnes of the product per annum.

*600:21. Domestic cheap water filters

(RRL, Jorhat—CSIR)

Water filter candles are used for removing harmful bacterial and other suspended impurities from drinking water. Filter candles, portable filter flasks and instant cartridge water filters are prepared according to the above process. Ion exchanger and bacteria inhibitor are used in making these products. Total capital outlay for making 50 candles per day is estimated at Rs.15,000.

*600:22. Fly ash for refractory products

(RRL, Bhubaneswar—CSIR)

RRL, Bhubaneswar, had developed a process for the utilisation of fly ash in refractory products. Bricks made using beneficiated fly ash ranging up to 60% alongwith plastic fire-clay and grog in different proportions finds suitability as fire-clay range of products and hot face insulation bricks. With increase in fly ash percentage the brick attains properties more of the insulating refractory wares, sacrificing its compressive strength. Suggested economic unit for this industry is for the production of 18,000 tonnes of mixed product per year.

*600:23. Low cost glazed wall tiles

(CGCRI, Calcutta—CSIR)

Low cost glazed wall tiles with adequate crazing resistance and impact strength have been developed. The technology is based on red clay gangetic silt deposit of Palta and Howrah, with low maturing temperature (950°C) and offers a means for considerable saving in energy. These tiles have good potentiality in the building industry, public toilets, railways, etc.

600:24. Prestressed concrete monoblock broad gauge sleepers

(SERC, Madras—CSIR)

Prestressed concrete sleeper is a highly sophisticated product and is different from other prestressed concrete units, particularly in production technology. The difference arises from the fact that mass manufacturing methods have to be employed for these products. The process developed at SERC is based on the long line method of prestressing. The estimated demand of the railways for this product is about 10 to 15 lakhs per annum. The fixed capital on plant and building for a plant of 50,000 sleepers capacity per annunm is about Rs.43 lakhs, working capital requirement being about Rs.31 lakhs. The cost of production comes out to be approximately Rs.300 per sleeper.

600:25. Asbestos cement and similar materials from amphibole variety of asbestos

(CFRI, Jealgora—CSIR)

Asbestos is based in the manufacture of asbestos cement products such as AC sheets, pipes, etc. SEU for production of asbestos sheet is 40 tonnes per day.

*600:26. Fly ash bricks

(CFRI, Jealgora—CSIR)

With a view to finding a suitable avenue for disposal of fly ash as well as to meet the needs of the building industry, the Institute has been able to produce sintered bricks, blocks, tiles, etc. The total capital outlay for a plant production of 25 million bricks per annum will be about Rs.90 lakhs (1987).

600:27. Self-setting agent for sodium silicate sand process

(NML, Jamshedpur—CSIR)

The use of sodium silicate as a binder for mould and core production is well established, carbon dioxide being used as a hardening agent in the conventional process. The NML has developed a reagent which when used with the sodium silicate sand mixture results in a self-setting mix requiring no further treatment for preparation of moulds and cores. The process is versatile and economical allowing considerable scope for adjustment of bench life and setting time to suit individual requirements. The knockout properties are superior to those of the conventional process.

600:28. Ferrocement storage bins

(SERC, Roorkee—CSIR)

It is a simple semi-mechanised process of casting thin ferrocement cylindrical units. This process does not require any sophisticated equipment or power and suits well for the rural areas. The process consists of a inner mould for the cylindrical units.

600:29. Fibre reinforced concrete (FRC) manhole covers

(SERC, Madras—CSIR)

FRC manhole covers provide an

alternative to the conventional cast iron manhole covers used in water and sewerage mains. They are made from steel reinforced cement concrete with the addition of high tensile cut steel fibres in correct proportions. Fibre reinforced concrete possess superior tensile, wear, impact and fatigue properties over the cast iron.

Detailed investigations and field trials have been carried out on the fibre reinforced concrete over the past several years. The FRC covers satisfy the reaquirements prescribed in the relevant Indian Standard Code for manhole covers It is about 60% of the cost of CI manhole covers.

600:30. Brick making machine

(CBRI, Roorkee—CSIR)

This is a plant for automatic shaping, moulding making which are now outmoded. The machine can produce 3000 wirecut bricks per hour with low rate of power consumption. The raw material is clay, water and electricity as utility. Capacity of production is 9 million bricks per annum. The capital investment required is Rs. 6 lakhs.

600:31. High draught continuous kiln for burning building bricks

(CBRI, Roorkee—CSIR)

The kiln can function throughout the year. It is thermally as efficient as Hoffman and consumes as low as 120 kg/1000 bricks compared to 183-200 kg/1000 bricks normally consumed in Bull's kilns.

Estimated cost of the kiln with a capacity to produce 30,000 bricks per day is Rs.4.4 lakhs, including machinery and civil works.

600:32. Plastic composite panel for partitions, claddings, flush doors

(CBRI, Roorkee—CSIR)

Plastic composite panels are basically combinations of plastics with conventional materials which often provide properties that are not attainable by the individual constituent materials. Core materials broadly in use are polyurethane and polystyrene foams, paper honey-comb, aluminium beam grid and wooven fabrics.

These panels possess excellent sound insulation, built-in decoration, easy installation and low maintenance. These are extremely light weight materials having very good thermal insulation and are suitable for partitions, claddings and fush doors. Cost of this composite is expected to be between Rs. 200 to 250 per sq. m. for 2.5 cm thickness depending upon the type of surfacing material used.

600:33. Sand lime brick

(CBRI, Roorkee—CSIR)

In India much attention has not been paid to the manufacture of calcium silicate bricks, popularly known as sand lime bricks, which can be used as a building material in place of clay bricks. The walls built of these bricks need no plastering.

At present the machinery for making sand lime brick is not readily available in the country. For a plant capable of manufacturing one crore bricks per annum, the initial requirement of foreign exchange is estimated as Rs.40 lakhs and annual recurring foreign exchange equivalent ot Rs.18 lakhs. Cost of manufacturing the bricks works out to be Rs.600 per thousand (1987).

600:34. Fly ash sand lime brick

(CBRI, Roorkee—CSIR)

Experiments at the laboratory have shown that fly ash obtained from thermal power stations using pulverised coal can be substituted in part for sand in making fly ash sand lime brick. The bricks produced are of uniform and smooth surface and a saving of about 30 per cent in the mortar and plastering is expected. The bricks can be used within 24 hours of their manufacture.

The capital investment for a plant for manufacturing 3,000 bricks per hour, working in three shifts for 300 working days a year is estimated to be Rs. 4 lakhs.

600:35. Laying of foamed concrete for thermal insulation of concrete shell and sloping roofs

(CBRI, Roorkee—CSIR)

Shell roofs are often recommended for

large span structures like industrial and public buildings. These shell roofs are however quite inadequate for protection against solar heat and other weathering agencies like moisture, rain etc. A technique has been evolved for laying foamed concrete on shell roofs and sloping surfaces. The laying can alone be in sections and the control of thickness of the insulation layer can be easily controlled.

600:36. Fibrous gypsum plaster boards

(CBRI, Roorkee—CSIR)

Fibrous gypsum plaster boards are manufactured from gypsum plaster slurry, reinforced by organic fibre material. Owing to their high insulation and fire resisting properties, these boards find wide application in office buildings, banks, auditoriums, etc. These may also be used for inside panelling in place of plaster and the construction will be faster.

Capital investment required for the production of 120 boards per day of three shifts of size 120 cm×60 cm×12 mm each of 300 working days per annum is estimated to be approximately Rs.6.5 lakhs. The cost of production is about Rs.19.40 for even board.

600:37. Prestressed concrete poles with HSD bars

(SERC, Madras—CSIR)

It is simple, appropriate technology of making prestressed concrete poles using high strength deformed bars. The use of high strength deformed bars and portable stressing beds make the technology more appropriate to Indian conditions than the method using high tensile steel wires.

The validity and performance of the techniques have been tested on a pilot bed and also tried out by a user. The poles showed better performance over identical reinforced concrete poles. Suggested plant capacities are 1,000, 3,000 and 7,000 units per annum.

600:38. Light weight bricks

(RRL, Trivandrum—CSIR)

The conventional clay bricks produced are used in the country as building construction material. The light weight bricks made of clay coconut pith mix can now also be conveniently used in building construction. The SEU for this industry is 10,000 bricks per day of the shift with a capital investment of Rs.8.75 lakhs. This excludes cost of land and building (1985).

600:39. Single fired matt glazed ceramic tiles for flooring and facing

(CGCRI, Calcutta—CSIR)

The Institute has developed an appropriate technology for the manufacture of single fired matt glazed ceramic tiles which could be easily adopted by small scale sector with their limited resources. The product obtained by this process is as per IS: 2838-1964.

The tiles may be used for flooring, interior and exterior decoration. This can also find vast market in low cost housing for rural populations.

The capital investment for a plant of capacity 810 MT finished goods per annum is Rs.28.8 lakhs.

*600:40. Plaster of Paris & building plaster by fluidised bed calciner

(NBO, New Delhi and SRI, Delhi)

Large quantity of plaster is used in the ceramic industry and in making various wall plasters. Conventional process does not give product of uniform quality. The process developed at SRI has several added advantages over the conventional process. SEU for this industry is 10 tonnes of building plaster and 5 tonnes of plaster of Paris per day. Estimated capital outlay is Rs.2.88 lakhs and Rs.2.75 lakhs respectively.

600:41. Latex cement coating for the protection of reinforcement in cellular concrete

(CBRI, Roorkee—CSIR)

The Institute has developed a protective coating for reinforcement. This coating can be manufactured from indigenous raw materials and gives satistactory protection against corrosion.

Following processes are also available for licensing:

1. **Bulding blocks (Latoblocks) from lateritic soils**
(SERC, Madras—CSIR)

*2. **Submerged arc welding fluxes**
(NML, Jamshedpur—CSIR)

3. **Screed vibrator for compaction in concrete**
(CRRI, New Delhi—CSIR)

4. **Labour-intensive, hydraulic, building block machine**
(SERC & MERADO of Madras)

5. **Semi-automatic building block making machine**
(SERC & MERADO of Madras)

MECHANICAL ENGINEERING INDUSTRY

CODE 700

700:1. Coconut husk chipping machine
(CBRI, Roorkee—CSIR)

The machine developed performs the chipping of the coconut husk without separation of the pith. The pith embedded in the coconut husk fibres contains reactive ingredients which during the process of making particle board undergo a chemical change and impart sufficient bond strength between the chips to form a strong board.

***700:2. Brick extrusion machine and automatic reel type cutting table**
(CBRI, Roorkee—CSIR)

The brick extrusion machine is of double deck design with provision for vacuum chamber and straight barrel for housing of the main auger. The brick extrusion machine is of semiautomatic type and has an automatic reel type cutting table the cost of production of the brick extrusion machine has been estimated at about Rs.1.75 lakhs and that of cutter about Rs. 25,000.

***700:3. Tractor**
(CMERI, Durgapur—CSIR)

The tractor has been designed at CMERI. The tractor uses two cylinder air-cooled Kirloskar engine and has a novel type of single level automatic depth-cum-draft control hydraulic system. The tractor has been fully tested at Tractors, Testing and Training Centre, Budni.

***700:4. Portable oxy-gas cutting machine**
(CMERI, Durgapur—CSIR)

Portable power driven machine running on rails has been developed for oxy-gas cutting of plates up to 75 mm thickness. It can be used for straight line and circular cuts. The speed varies from 15 to 90 cm per minute. The cutter adjustments are 5 cm per minute. The cutter adjustments are 5 cm vertical and 7.5 mm transverse and the level adjustment is of 70%. The weight of the machine is 5 kg excluding the weight of torch. The manufacturing cost of the machine excluding the torch would be around Rs.900. The prototype has been successfully tested at the Institute.

700:5. TIG cutting machine
(CMERI, Durgapur—CSIR)

The constricted arc TIG cutting machine can be used for cutting of stainless steel up to 20 mm thickness and aluminium and copper up to 35 mm thickness. The constricted arc cutting method employs a constricted arc between tungsten electrode and the work piece with a high velocity gas stream. The arc is concentrated and localised upon a small arc operation of the job to be cut. The high arc temperature melts the metal. The machine is of portable nature and has a cutting speed of 20-250 cm per minute. The maximum current is 500 amperes, at 70-100 volts. The cost of manufacture of this machine may be around Rs. 25,000, excluding power source. The prototype has been successfully tested.

*700:6. Automatic submerged arc welding machine

(CMERI, Durgapur—CSIR)

The submerged arc welding machine is a portable machine consisting of three subassemblies namely, welding head, a voltage controller and a carriage. The machine utilizes arc voltage as the basic control parameter for the relative movement of the electrode with reference to the variation of the arc length. The machine has a welding speed of 10 to 150 cm per minute and can be used with both AC/DC power source. The prototype has been successively tested.

700:7. Pusa seeder

(IARI, New Delhi)

Several designs of seed drills came into market but could not gain wide popularity because of their exhorbitant cost. The design developed at IARI, New Delhi, is simple in operation and construction. The seed damage is less and has higher mechanical efficiency.

*700:8. Semi-automatic anchoring and locking devices for containers used in rail and road vehicles

(RDSO, Lucknow—Min. of Rlys.)

The device developed automatically locks the container having ISO type corner fittings for use with rail wagons or road vehicles when lowered and deposited on the wagon thereby eliminating any risk of the container being inadvertantly despatched in unlocked state.

700:9. Freight bogies for high speed operation

(RDSO Lucknow—Min. of Rlys.)

This is an improved bogie for goods stock of railways suitable for high speed operation and improved riding. It has a suspension system enabling smoother running of goods stock with longer travel springs and damping means and a torison plant to improve vertical and lateral riding. Excessive wear of rails and wheel flanges, uneven and excessive wear on general bearings will be prevented and occurrance of battering and breaking up of dust guards, layrinths etc., reduced.

*700:10. Milling of pulses—Dhals

(CFTRI, Mysore—CSIR)

The conventional methods of processing pulses are generally laborious, time consuming and highly wasteful. An economical process for dhal milling using improved technique and machinery has been developed by CFTRI. The process besides being independent of any climatic conditions gives higher yield. SEU for this industry is 1 tonne of dhal per hour. Estimated capital outlay is Rs.6.85 lakhs.

*700:11. Gasket from coir pith

(NCL, Pune—CSIR)

The gaskets are used in automobile oil engines and similar equipment as a substitute of rubberised cork sheets. The process consists of mixing the coir pith with neoprene and other ingredients and vulcanizing the mix in a press.

For a plant capable of producing 5.42 tonnes of the finished product per annum 3 tonnes of coir pith is required.

*700:12. Rubberised cork sheet from waste cork granules

(NCL, Pune—CSIR)

Rubberised cork sheets are used as gaskets in automobile oil engines. The process consists of mixing the waste cork granules with neoprene and other ingredients and vulcanising the mix. SEU is 3 tonnes of waste granules per annum.

700:13 RPEC dockage tester

(IIT, Kharagpur)

RPEC dockage tester is a laboratory device to test the impurities present in the paddy. It is a compound machine consisting of three rotary sieves contained in a sheet metal cylinder. The sieves have different size perforations to separate different size ingredients present in the paddy. Paddy is fed through a hopper on to the air blower and to chutes for collection of separated ingredients. The machine can be operated electrically or manually. The overall size of the machine is 90×55×65 cm. The weight is 30 kg and runs at 30 rpm.

*700:14. Automatic control on slasher sizing machine

(TAIRO, Baroda)

The textile mills are using conventional sizing machines without any automatic controls, which are essential and useful for better quality and higher efficiency looms for production of the fabrics. Automatic controls are essential and useful. TAIRO sizing controls consists of size box level control, constant size circulation equipment, automatic temperature control for size solution in the size box and temperature control device for the drying cylinders. These controls can easily be fitted on the existing sizing machines.

700:15. Mechanical nasal filter for treatment of inhalant allergy

(AIIMS, New Delhi)

Allergic disorders can be prevented if the patient does not allow the antigen to enter into his body. In the case of allergy due to inhalants, the antigen ordinarily enters the body through the nostrils. Nasal filters have been constructed and the results of their use have been seen of eleven patients suffering from various types of allergic disorders and the performance has been very satisfactory. It does not cause any side effect usually associated with medicines. The filter can be placed inside the nostrils and is not visible from outside. It can also be used by persons suffering from allergic disorders caused by bronchial asthma, allergic rhinitis, utricaria, atopic decmatitis and pompholy.

700:16. Earth auger

(RRL, Bhubaneswar—CSIR)

Earth auger finds application in agriculture in digging hole on earth surface for use in fencing, soil testing. It has got several advantages over the conventional tools. The device is very simple and cheap.

*700:17. Hand operated bellow pump

(RRL, Bhubaneswar—CSIR)

Hand operated bellow pumps are for lifting water for irrigation and other purposes from tanks and canals etc. The pump developed is easy to construct, less costly, low maintenance and easy to transport in field.

700:18. Automatic road unevenness recorder

(CRRI, New Delhi—CSIR)

The automatic road unevenness recorder is used to obtain speedy and complete record of unevenness of runway and highway pavements and other similar surface. It comprises of a single wheeled trailer mounted on a chassis towed by a vehicle at a speed of 30 km/h. The unit gives a quick and permanent record of the quality of the paved surfaces, pin points the irregularities on existing highways and the reading is free from human error. The capital outlay for 15 recorders per year is Rs. 1,12,000. The cost of production ot one unit is about Rs.22,000.

700:19. Flange lubricator

(South Eastern Rly., Kharagpur—Min. of Railways)

The flange lubricator is used on railway vehicles (locomotives and bogies) especially while negotiating a curve in order to inhibit wear on flanges and rails and also ensures smooth guidance around curves.

700:20. Cavityless mould casting

(NIFFT, Ranchi)

A cavityless mould casting process has been developed. The process is used for conventional type of pattern making and moulding work in a jobbing foundry. It is useful for producing large and intricate castings of iron and steel.

*700:21. Retractable anchoring and locking device

(RDSO, Lucknow—Min. of Railways)

Retractable anchoring and locking device is used for locking containers of railway rolling stock. The device can also be used on containers transported by any general engineering workshop having facilities for obtaining casting. The present market price is around Rs.700 for single fitting and Rs.1,200 for double fitting (1987).

*700:22. Citrus fruit juice extractor

(CFTRI, Mysore—CSIR)

The Institute has developed a machine which can extract juice from oranges and other citrus fruits. The process is based on extracting pure juice, ideal for concentration and can be used for fruit products and in confectionaries. The other grade which contains slight percentage of peel oil can be used for peparation of concentrated in evaporators. The fabricating cost of the extractor of capacity 10,000 fruit/hr is estimated at Rs.1,00,000 while the annual cost of process 18,000 tonnes of fruit juice is estimated at Rs. 48,650 excluding raw materials and packing.

700:23. Flat plate collector—tube and sheet

(NPL, New Delhi—CSIR: DST sponsored project)

The flat plate collector is a simple rugged device which, without orientation mechanism can effciently collect solar energy at moderate temperature levels. The flat solar collector basically comprises of solar radiation absorbing flat plate having imbeded tubes or channels beneath a transparent glazing or cover. The absorber plate is backed by suitable insulating material to reduce back and side losses. Absorber of the flat plate collector absorbs solar radiation and transforms this solar radiation in the thermal energy which is extracted by the heat extracting fluid flowing through the tubes or channels in contact with the absorbing plate.

700:24. Instantaneous braking system for 3-phase induction motors

(IIT, Delhi—DST project)

Braking of motors within a very short duration is quite essential for many industries like printing industries, process industries, mining, engineering industries etc. As such, a system has been developed based on the phenomena 'capacitor self-excitation' for braking motors within a duration of 0.5 to 2 seconds depending on the process conditions. The system employs multi-stage braking process. It has several advantages over the conventional mechanical and electrical braking systems. This could be used for motors up to capacity of 50 hp. By making suitable adjustments in the control circuit and also by addition of more capacitors, the system could be employed even for braking motors of higher capacity. The cost of the system ranges from Rs.1,000 to Rs.10,000 depending on the capacity of the motor.

700:25 Bore hole logger

(NGRI, Hyderabad—CSIR)

The device is used for the measurement of two electrical properties (potential and resistivity) in the bore hole. The system consists of a downhole electrode, logging cable, winch, measuring sheave ground electrode, cable motion sensing system, depth indicator, strip chart recorder, square wave constant current generator, static potential and resistivity separation module.

700:26. Vacuum guard

(IIP, Dehradun—CSIR)

It is a device for guarding the vacuum in a system and is used as a safety valve in vacuum distillation unit. It can be taken up a side product in a mechanical workshop producing any other item.

700:27. Paddy husk combustor-cum-heat exchanger

(Deptt. of Food/CMERI/CFRI)

For efficient utilisation of paddy husk a combustor-cum-heat exchanger system has been developed to dry parboiled paddy in rice mills. The system can deliver about 214-224 m^3 of hot air per minute at a temperature of 110°-120°C. Husk consumption is about 105 kg/hour. A batch of 5 tonnes or parboiled paddy could be dried in 4 to 4½ hours. All materials of construction are available indigenously. The combustor could be fabricated by parties having simple fabricating infrastructure.

700:28. Rice bran stabiliser

(IIT, Kharagpur—ICAR)

A continuous rice bran stabiliser has been developed for stabilising rice bran of capacity up to 100 kg bran per hour. The stabilisation could be carried out either by open steaming followed by conduction drying or by conduction drying alone. The stabilised bran with FFA content below 5% could be stored for a period of 2 months. All the materials for construction are available indigenously. The cost of fabrication of a stabiliser of 100 kg per hour capacity (machine with 2 tonne per hour rice mill) will be about Rs. 50,000. The operating cost is Rs. 1.5 per 100 kg of bran.

700:29. Tribotester

(MERADO, Pune & CMERI, Durgapur—CSIR)

Tribotester is a versatile unit for measurement of co-efficient of friction, wear of material and other different tribological studies. By this unit, wear is measured on the principle of "Pin on Roller" and co-efficient of friction on "Pin on Disc". Loading of the specimen is done by a specially designed holder. This item would be suitable to the industries who have got standard workshop facilities with them and wish to take up as an additional item in the range of manufacturing products. The total cost of the project is nearly Rs.15 lakhs for a plant of capacity of 60 machines per year.

700:30. Hydraulic bolt tensioner

(CMERI Durgapur—CSIR)

Presently conventional tightening equipment viz. ordinary wrenches, spanners and torque wrenches are used, but these do not ensure uniform tightening. Hydraulic bolt tensioner is an equipment for tightening bolts at desired stress avoiding any torsional effect. Hydraulic bolt tensioner are widely used in the chemical and process plant, general engineering industries, automobile industry etc. The technology is suitable to those parties who have got workshop facilities with them and wish to diversify the range of their product. The total cost of the project for a plant capacity of 600 units per year in nearly Rs.6 lakhs.

700:31. Hydraulic coil expanding and spreading machine

(CMERI, Durgapur—CSIR)

Hydraulically operated coil expanding and spreading machine is meant for forming the closed loop stator coil automatically in single operation that ensures exact and identical coil and simplifies the manufacturing process leading to increase in productivity with quality effectiveness. The total capital investment on a plant of capacity 30 machines per annum is Rs. 50 lakhs.

700:32. Industrial sewing machine

(MERADO, Ludhiana & CMERI, Durgapur—CSIR

The machine is ideally suitable for sewing all types of closing seams on different garments and hosiery goods. The following type of operations can be performed simultaneously and continuously with this machines.

i) Stitching "closing seams" with double chain lock stitch, Type 401.
ii) Edge trimming for equal margin from seam.
iii) Over edging "trimmed edges" with three thread over lock stitch, Type 504.

The total investment on a plant of capacity of 3,000 machines per annum is estimated at Rs.1.5 crores.

700:33. Automatic cloth cutting machine

(MERADO, Ludhiana & CMERI, Durgapur—CSIR)

The electric cloth cutting machines are deployed extensively in the modern garment manufacturing industries for cutting of cloth according to a desired pattern for mass scale production of garments. The machine also finds application for cutting leather, rexine and rubber for imparting desired shape for manufacture of various goods. The total capital investment on a plant of capacity of 500 machines per annum is Rs.14 lakhs.

Following processes are also available for licensing:

* 1. **Powered scaffold hoist**
(CBRI, Roorkee—CSIR)

* 2. **Manual scaffold hoist**
(CBRI, Roorkee—CSIR)

* 3. **Unit frame scaffolding**
(CBRI, Roorkee—CSIR)

4. **Power trowel**
(CBRI, Roorkee—CSIR)

5. **Tamping machine**
(CBRI, Roorkee—CSIR)

* 6. **Rotillor**
(CMERI, Durgapur & CRRI, New Delhi—CSIR)

* 7. **Unevenness indicator**
(CRRI, New Delhi—CSIR)

* 8. **Profilograph**
(CRRI, New Delhi—CSIR)

9. **Rotating cantilever type fatigue testing machine**
(NAL, Bangalore—CSIR)

10. **Inert gas shielded arc welding process for leaded bronze and filler rod prepared**
(RDSO, Lucknow—Min. of Rlys.)

11. **Welding of rail joints by metal arc processes**
(RDSO, Lucknow—Min. of Rlys.)

12. **Synthetic gem stones**
(NCL, Pune—CSIR)

13. **Eradication of submerged aquatic weeds—a mechanical device**
(CIFT, Cochin)

14. **Liquid air/nitrogen dewars**
(NPL, New Delhi—CSIR)

*15. **Solid carbon dioxide machine**
(NPL, New Delhi—CSIR)

16. **Ice shaving machine**
(NPL, New Delhi—CSIR)

17. **Laboratory model kapas extractor**
(CTRL, Bombay)

18. **Press-in type door lock**
(RDSO, Lucknow—Min. of Rlys.)

19. **Inboard/outboard drive**
(CIFT, Cochin)

20. **Berseem harvester**
(NDRI, Karnal—ICAR)

21. **Regenerative pump**
(CMERI, Durgapur—CSIR)

22. **Centrifugal clutch**
(CMERI, Durgapur—CSIR)

23. **Suspension system for bogies**
(RDSO, Lucknow—Min. of Rlys.)

24. **Road-cum-rail cycle**
(RDSO, Lucknow—Min. of Rlys.)

25. **Printed circuit board drilling machine**
(CEERI, Pilani—CSIR)

INSTRUMENTS AND DEVICES INDUSTRY

CODE 701

701:1. **Thermal conductivity tester**
(CGCRI, Calcutta—CSIR)

The instrument developed on hot wire technique determines rapidly the thermal conductivity of non-electrical conducting refractory materials up to temperature range between 25°C to 1,250°C. All the raw materials required for fabrication are available indigenously. Cost of production/unit is about Rs. 90,000 (1987).

701:2. **Digitl corrosion meter**
(NAL, Bangalore & CEERI, Palani—CSIR)

The device is used for continuous and rapid determination of corrosion rate of metals in contact with conductive media like water and salt solutions. The instrument developed is capable of reading the corrosion rate of metals quickly unlike the conventional methods. Cost of production/units is Rs.6,000 (1987).

701:3. Recording stack smoke meter
(CSIO, Chandigarh—CSIR)

The instrument is used in the measurement of density of smoke released from chimneys of thermal power stations, factories. The device operates on the principle of attenuation of collimated beam of light as it traverses the column of smoke rising in a stack or chimney. The cost of production/unit is Rs.25,000 (1987).

701:4. Audio distribution amplifier
(AIR, New Delhi)

The distribution amplifier feeds a single audio input programme to a number of output lines and isolates each output from the faulty conditions of other outputs. It replaces the conventional multiple pad distribution system. The cost of production per unit is about Rs.3,000 (1987).

701:5. Lead zirconate titanate (PZT) for high powered transducers
(ARDE, Pune—DRDO)

PZT-4 and PZT-8 ferro-electric hard ceramic materials have been developed. The grades are suited for high powered SONAR for underwater acoustics, cigarette lighters, high powered ultrasonic transducers. etc.

701:6. Digital salinity tester
(CSIO, Chandigarh—CSIR)

The device is an instant electrolytic conductivity tester developed to provide a field investigator with a simple and quick means to determine the conductivity of solutions related to water, waste water, soil and other matters. The cost of production per unit is about Rs.5,000 (1987).

701:7. KW FM transmitting antenna
(AIR, New Delhi—Min. of Information and Broadcasting)

A horizontally polarised 3 KW FM transmitting antenna (ring type) has been developed. The frequency of operation is 107.1 MHz.The cost of the components required for fabrication of one unit is about Rs.30,000 (1987).

701:8. Digital readout system
(CSIO, Chandigarh—CSIR)

The device is used for precisely monitoring the tool movement on machines like milling, grinding and jig boring. Optical sensing techniques have been used to provide precise and fast measurements. It gives a continuous dimensional display of the tool and slide position, even while the machining is in progress, thus eliminating the need of conventional measuring instruments. The cost of production per unit is about Rs.12,000 (1987).

701:9. Foil type resistance strain gauge
(NAL, Bangalore—CSIR)

Strain gauges with epoxy backing in gauge lengths-1 mm, 1.5 mm, 3 mm. 5 mm, 10 mm in resistance ranges of 120 and 350 ohms have been developed. These gauges are used for measurement of mechanical strains on surfaces of structures and also in the measurement of pressure, load, acceleration as functions of strains. The total capital outlay for puting up a minimum economic unit of 25,000 gauges per year has been estimated at about Rs.6 lakhs (1987).

701:10. S-Band signal generator for TVRO and RN termical testing
(AIR, New Delhi)

The device provides video and audio modulated S-Band RF output which can directly be fed to the feed point of the TVRO and the entire TVRO baseband can be checked. The cost of production per unit is about Rs.30,000 (1987).

701:11. Digital colorimeter
(CSIO, Chandigarh—CSIR)

The device is used for the measurment of five blood constituents i.e. Bilirubin, Albumin Protein, Urea and Glucose to assist the physician in confirming his diagnosis. The device is useful for primary health centres so that the routine and often required tests on blood can be carried out at the site.

The device uses conventional technique of using filament lamp, filters and moving coil meter. The cost of production is about Rs.2,500 per unit (1987).

701:12. Test kit for microbiological quality of drinking water

(DRDE, Gwalior—DRDO)

It is a simple device to test the potability of drinking water. Waterborne diseases like typhoid, cholera, diarrhoea and jaundice which are caused by polluted water supply can easily be tested by the device. The device takes about 18 hours in performing these tests in comparison to 72 hours taken by the conventional method.

701:13. Battery operated finger print developer

(Central Finger Print Bureau, Calcutta)

The device develops the finger prints without spoiling its characteristics. The gadget is the assembly of a blower placed in a centrifugal chamber connected with a 9 volt motor fitted with mini plates acting as a fan with outlet of the air to the powder chamber having a nozzle for spraying powder through jet blocking system. The cost of production is about Rs.200 per unit (1987).

701:14. X-Y Position coordinate locator system

(CSIO, Chandigarh—CSIR)

The system is used to take measurements of bubble chamber photographs projected onto a horizontal table for bubble chamber scanners. The optical sensor based on moire finge phenomency is used for measuring linear displacement. The cost of production is about Rs. 14,000 per unit (1987)

701:15. Microprocessor based controlled unit for automated multi-electrochemical protection system

(CECRI, Karaikudi—CSIR)

The device is used for monitoring multiple units of magnetic amplifiers for servomatic controls or silicon control rectifier normally employed for automated electrochemical protection. The microprocessor compares the set potential with the cell potential value and switches on/off. The current through the SCR at a very high speed sequentially maintains the potential. The capital outlay for a unit capable of producing 150 nos. of 5A/50V microprocessor control unit is about Rs. 10 lakhs. Cost of production per unit is about Rs. 30,000 (1987).

701:16. Design and fabrication of inductive voltage dividers

(NPL, New Delhi—CSIR)

The inductive voltage dividers (IVD's) are widely used in R&D laboratories as a precision measurement devices in AC bridges, filter testing, phase angle measurement and AC voltage ratio standards. The laboratory has designed and fabricated 4, 6 & 8 decade IVD's to meet the requirement of R&D institutions. Market price of imported IVD's is ranging from Rs.20,000 to Rs. 40,000.

701:17. Thin film optical coating

(NPL, New Delhi—CSIR)

The laboratory has developed the process of thin film optical coating suitable for (i) anti reflection coating, (ii) interference filters, (iii) metallic & all dielectric type beam splitters, (iv) neutral density filters. This type of coating is extensively used in optical devices such as camera lenses, prisms, interference filters & spectro photometers to get the desired optical characteristics. At present the demand is being met through import. Estimated capital outlay is Rs.36 lakhs, excluding the cost of land and building for 500 mm dia vacuum coating plant.

701:18. Electro stimulator

(HARTRON, Chandigarh)

Electro stimulator is a device to provide special types of pulses at different parts of the body to cure a number of diseases. A microprocessor based electro stimulator which can generate various types of waveforms like continuous square, discontinuous square, saw tooth, triangular and dense disperse. The instrument is portable and can be fitted in a briefcase for outdoor use. The cost of production is about Rs.3,000 (1987).

701:19. Microprocessor based telephone dial tester
(HARTRON, Chandigarh)

A microprocessor based instrument has been designed that checks all the necessary parameters such as count, make break ratios and speed. by visual indication one can know whether all the parameters are within the specified range or not. The instrument works both on 220V main supply or 50V telephone exchange supply. The cost of production is about Rs.2,000 (1987).

701:20. Educational robot
(HARTRON, Chandigarh)

The device is a light duty robotic arm with 5 degree of freedom and is intended primarily for low cost educational and experimental usage. It is a simulation of human arm and can lift things from one place to another and can rearrange objects as programmed and taught. The cost of production of complete unit along with microcomputer, monitor and disc drive is about Rs.25,000 (1987).

701:21. Digital clock-cum-thermometer
(HARTRON, Chandigarh)

The device show time and temperature alternatively for 5 seconds on a common display. LED display size has been made large enough so as to be visible from quite a good distance say 75 to 100 ft. LSI circuitry ensures accuracy of time upto ±15 sec/month and of temperature upto ±1°C. The device works on 230V mains with battery back up. The cost of production is about Rs.2,000 (1987).

701:22. Semiconductor trainer
(HARTRON, Chandigarh)

The device enables beginners in the field of electronics to learn about basic devices like diodes, transistors including field effect transistors and power devices like SCRs, diodes etc. The device has been provided with various values of resistors, potentiometers and capacitors so that a number of combinations can be tried. The cost of production is about Rs.2,000 (1987).

701:23. Eprom programmer
(HARTRON, Chandigarh)

The instrument is designed to programme EPROMs—2716 and 2732 but with minor changes can be extended for other EPROMs as well. The data is entered through a key board using toggle keys and verification of entered data is possible in READ mode. The cost of production is about Rs. 2,000 (1987).

701:24. Linear IC trainer
(HARTRON, Chandigarh)

The device enables beginners in electronics to learn about linear devices like amplifiers, voltage, comparators, operational amplifiers which are used in almost all the electronic instruments. The trainer is provided with a number of resistors, capacitors, potentiometers etc. so that all possible combinations can be tried. The device works on 220V mains. The cost of production per unit is about Rs. 1,200 (1987).

701:25. TTL logic trainer
(HARTRON, Chandigarh)

The device enables the beginners in electronics field to learn fundamentals of digital electronics. The device has been provided with various types of gates and flip flops so that all possible combinations can be tried by the instrument. The device works directly on 220V mains. The cost of production per unit is about Rs.800 (1987).

701:26. Anemometer
(HARTRON, Chandigarh)

The instrument can measure velocity of wind which is displayed in meter per second on an indicator in analogue form. The device is capable of storing the minimum and maximum value of wind velocity during any set interval of time. The cost of production per unit is about Rs.600 (1987).

701:27. Electronic inverter
(HARTRON, Chandigarh)

The device has been designed to ensure uninterrupted power at 50 Hz, 230 Volts, even during power failure. The instrument is suitable for running fans, televisions, mixers, bulbs, tubelights etc. The cost of production per unit is about Rs.1,500 (1987).

701:28. Electronic STD disconnector

(HARTRON, Chandigarh)

The device is a small inconspicuous instrument which can be conveniently connected to the telephone receiver to disconnect the telephone from the STD line with the help of a lock. When the STD line is to be opened the lock can be opened by simply using the key provided with the instrument. There is no need to disconnect the whole instrument. The cost of production per unit is about Rs. 150 (1987).

701:29. Microprocessor trainer kit

(HARTRON, Chandigarh)

The kit has been developed to enable students to learn fundamentals of microprocessors. The kit is built around popular 8085 microprocessor and features intensive LED display system monitor software and a key board. A stabilised 5V power supply is sufficient to operate the system. The cost of production per unit is about Rs.2,500 (1987).

701:30. Thermocouple-type digital temperature indicator

(HARTRON, Chandigarh)

The instrument shows digital display of temperature up to 1200°C. It uses K-type thermocouple sensor and is based on latest LSI circuitry. It works on 220V AC mains and is portable. The cost of production per unit is about Rs.2,000 (1987).

701:31. Water level sensor

(HARTRON, Chandigarh)

It is used to detect the level of water in the radiator of a vehicle. When after evaporation, the level of water falls down to a predefined level it gives a visual signal and thus water can be added if necessary. Level of water is sensed indirectly using a thermistor. The device is surge and short ciruit protected. The cost of production per unit is about Rs.50 (1987).

701:32. Industrial timer

(HARTRON, Chandigarh)

The device can be used to measure time intervals up to 999 seconds with a resolution of one millisecond. The time is shown on a three digit LED display. The cost of production per unit is about Rs.1,000 (1987).

701:33. Vasec apparatus

(CSIO, Chandigarh—CSIR)

A simple, inexpensive but reliable and effective electronic-Vasec apparatus for use in vasectomy procedures has been developed. The instrument provides bipolar electrocoagulation of the Vas deferens lumen to achieve healing of the Vas with a minimum of trauma, scar tissue and sperm antibody formation. The electrocoagulation effect is produced by high frequency currents of appropriate wave shape when they are passed through the tissues. For the plant capacity of 200 units per annum, the investment required on equipment is about Rs.50,000. The cost of component is Rs.625 per instrument (1987).

701:34. Dialysis machine

(CSIO, Chandigarh—CSIR)

A monitoring and control unit for the artificial kidney (dialyser) has been developed. The unit provides a continuous supply of solution of controlled concentration at the right temperature and pressure to the dialyser. The flow of the dialysate to the dialyser takes place under the influence of the effluent pump. The pressure of the effluent on the return line is measured by strain gauge pressure transducer.

Components of worth about Rs.26,000 are required for the fabrication of the device (1987).

*701:35. Cardiac monitor

(CSIO, Chandigarh—CSIR)

It consists of cardioscope, heart rate monitor with alarm and cardiac pace maker. It is used for the patients suffering from cardiac arrest.

*701:36. Microfilters

(CSIO, Chandigarh—CSIR)

Microfilters are filter cartridges used for a variety of filtration where clean and compact filtration is required.

These filters can be used for the removal of the suspended particles etc. Process consists of reacting a thermosetting resin with high grade pulp. The resin is well mixed with pulp and dried. This is a powdered and sieved.

SEU for this industry is 60,000 pieces per annum.

701:37. Glass apparatus for specific surface determination of particulate materials and course particulate dust

(CECRI, Karaikudi—CSIR)

The Institute has developed a glass apparatus of one standard design which is useful for one specific surface determination of particulate material and course particulate dust in the range of specific surface area values 100 to 10,000 cm^2/cc. SEU for this industry is 3,000 apparatus per year.

701:38. Electronic reflux ratio timer

(RRL, Hyderabad—CSIR)

· The device can be used to select the reflux ratio for distillation columns particularly in chemical/pharmaceutical processing industry.

*701:39. R.F. Induction furnace (1.2, 3, 5, & 12.5 kW)

(CEERI, Pilani—CSIR)

The Institute had developed induction furnaces of power output 1.2 kW at 13.56 MHz (nominal), 3 kW at 450 kHz (nominal), 5 kW at 1 MHz (nominal) and 12.5 kW at 450 kHz (nominal). By using induction furnaces, precise and controlled heating of the components placed inside the furnace can be achieved with ease. These furnaces find various applications like, soldering, surface hardening of shafts, gear teeth hardening, stress relieving and annealing, etc.

701:40. Cardiotocograph

(CSIO, Chandigarh—CSIR)

Cardiotocograph is an electro-medical instrument extremely useful in Obstetrics & Gynaecology Departments in hospitals for monitoring foetal heart rate and labour activity which when studied simulataneously gives the status of the foetus and the mode of delivery to be followed.

701:41. EEG biofeedback monitor

(IIT, Madras—DST sponsored project)

The instrument developed, works on nonvolitional biofeedback (NBF) modality. The NBG monitor is used along with an EEG recording system for obtaining clinically significant changes in EEG. Provision is also made for recording the concurrent changes in EEG on the multi channel recorder.

The NBF instrumentation consists of amplifiers, a bank of filters to filter out delta, theta, alpha and beta bands and driver circuits for driving the intensity of a lamp in synchronism with the filtered component of the desired filter and this visual output constitutes the feedback signal.

*701:42. Minicardioscope

(CSIO, Chandigarh—CSIR)

Minicardioscope is a portable, battery operated handy unit extremely useful to doctors to visualise instantaneously the ECG of the patients. The instrument has integrated electrodes for direct application on patients' thoracic region. Frequency response 0.1 Hz to 70 Hz, sensitivity 0.5 mV/cm to 3mV/cm power source Ni-Cd cells 5.2V.

*701:43. Patient monitor system

(DEBEL, Bangalore—DRDO)

In modern hospitals continuous monitoring improves the attention given by the hospital staff to a patient with the most critical conditions and yet not neglecting other patients. The system involves continuous measurement of physiological parameters like respiration rate, body temperature, blood pressure and heart beat.

*701:44. Internal/external DC defibrillator with synchroniser

(DEBEL, Bangalore—DRDO)

It is used for delivering a high voltage electrical shock to the heart of a person to cause it to stop quivering or fibrillating. The heart then returns to normal activity after an initial stoppage for a few seconds. The fibrillation may be ventricular or arterial in origin.

701:45. Standard band with 1 port and 4 port coaxial circulators in S-C bands
(DLRL, Hyderabad—DRDO)

Three port circulators are used in transmitter and receiver chains of microwave communication and radar systems. They can be used as isolators, by terminating the isolated port with a matched oscillator used in such communication networks. Four port circulators are used as duplexers in transponders and isolation devices.

701:46. Weston standards cells
(CECRI, Karaikudi—CSIR)

The Institute had developed three types of cells i.e. type-I (10 cm dia×10 cm height), type-II (20×20×70 mm) and type-III (22 mm dia ×60 mm height). These cells conform to ISI specifications and each cell consists of two electrodes—the cadmium and the mercury/mercurous sulphate.

701:47. Wave energy electrical generator
(Madras Port Trust, Madras)

Light buoy is an important aid to navigation in modern ports. They are used for demarcation to help the pilot to determine the safe course in a dredged channel or to warm him of obstructions to ship's navigation. This generator charges the light buoy's batteries automatically.

701:48. Non-fade ECG monitor
(CSIO, Chandigarh—CSIR)

This is a continuously monitoring cardiac instrument with non-fade display on a CRO screen giving the appearance of ECG paper. The system is extensively useful in coronary care unit, emergency wards in hospitals for continuous patient monitoring over long periods.

701:49. Surface acoustic devices
(IIS, Bangalore)

The institute had developed inter digital transducers, delay lines and various other surface wave devices by conventional thin film and photolithographic techniques. These devices provide VHF-UHF signal processing functions not readily available by other means.

701:50. Piezoelectric micrometer and piezoelectric displacement transducer
(NPL, New Delhi—CSIR)

These devices are employed in a wide variety of optical, mechanical and electro-optical systems both in industrial and research applications such as to stabilize amplitude and frequency in continuous wave lasers and to examine its power tuning curve. SEU 200 pieces/annum and fixed capital Rs.1 lakh.

***701:51. Bonded wire strain column type load cell**
(NAL, Bangalore—CSIR)

The Institute has developed a device for 10 tonnes compressive load consisting of a solid cylindrical steel billet to which four bakelitised wire strain-gauges are bonded at its mid portion. Suggested economic unit is 600 unit per annum. Total fixed capital is Rs.1.5 lakhs.

701:52. Dual frequency electro-magnetic unit (ground)
(NGRI, Hyderabad—CSIR)

The device is used to detect underground ore bodies like massive metallic sulphides under a cover of poorly conducting over-burden. The instrument is based on the principle of electo-magnetic induction.

701:53. Proton procession magnetometer
(NGRI, Hyderabad—CSIR)

The device is used for the measurement of total vector of the Earth's magnetic field at a place. This quantity can be interpreted in geological terms in prospecting for minerals and ground water and investigations for bedrock topography in dam site selections.

701:54. Vibrotone: A non-destructive vacuum measuring instrument

(CEERI, Extension Centre, Madras—CSIR)

Measurement of vacuum and pressure are essential for food preservation in sealed cans. Present practice is a destructive method using a piercing type vacuum gauge. Vibrotone determines level of pressure/vacuum as low, optimum, high and excess and the same is digitally displayed as L, O, H, & E respectively. About 600 cans per hour can be tested with this instrument. Accuracy of the reading is about +2%. All the equipment and raw materials/component except oil filled high voltage capacitors are available indigenously.

701:55. Digital instrument—"Autobas"

(CEERI, Ext. Centre, Madras—CSIR)

A digital electronic instrument useful for measurement of electrical resistance of battery separators and porous diaphragms. It is suitable for efficient quality control during production and also for evaluation of the separators by battery manufacturers. Accuracy of the instrument is about 0.01 ohm-cm^2/mm thickness. All the equipment and raw materials/component required for this are available indigenously.

701:56. Automatic slide projector

(CSIO, Chandigrh—CSIR)

The instrument consists of a quadrupled objectives of f/2.5 relative aperture and 75 mm focal length, a triplet condensing system for uniform illumination of transparency, a toughened heat absorbing glass filter to prevent heat damage of transparency during longer projection times, a metallic reflector. The design incorporates an interchangeable f/2.5, 100 mm focal length objective suitable for projection in big auditoriums. Estimated control facility for either reverse or change over of transparency and focusing has been provided.

701:57. Rom based multipoint temperature indicator

(CSIO, Chandigarh—CSIR)

The instrument is based on the advanced digital technology for the precise measurement of temperature in industrial, engineering and research institutions. EPROM has been used to accommodate the programme of linearisation of six widely used thermocouples J, K, T, R, S&E. Automatic cold junction compensation has been provided. For a highly non-linear thermocouple maximum number of segments could be about 32. The temperature can be measured from—100°C with an accuracy of 0.25% FSD. 3½ digit display with automatic polarity indication has been provided.

701:58. Micro in vitro test kit

(NICD, Delhi—CSIR)

Micro in vitro test kit is used to conduct tests to determine whether the Falciparium malaria has developed resistance to commonly used drug chloroquine and to determine the efficacy of alternate drugs. The present available kits mainly used by National Malaria Eradication Programme is imported and is supplied by WHO. The kit developed at NICD is more compact, less expensive and more comprehensive one.

701:59. Eddy current precision wire tensioner

(NAL, Bangalore—CSIR)

The device is used for frictionless tension adjustment in precision coil winding machines, for winding fine gauge wires (SWG 44 and onwards) to manufacture precision components like potentiometers, strain gauge, galvanometer, etc. It minimises the rejections that normally occur in existing mechanical tensioner due to improper tension in winding of components. SEU is 300 numbers per annum. The fixed capital required is Rs.2 lakhs.

701:60. Bone stapler with inter-changeable heads and staple carrier

(Dr. Debabrata Mukhopadhay, Orthopaedic Surgeon)

Bone stapler and staple carrier is an instrument for fixing staples on fractured bones in the course of orthopaedics operations. The instrument is designed to perform bone stapling operation by "No Touch" technique. This design is a combination of five different units to one compact unit.

701:61. Inclinometer

(RDSO, Lucknow—Min. of Rly.)

This is a single device consisting of two spring pendulum fixed with electrical resistance strain gauge with a cone at the bottom. This spring pendulum is encased in two concentric steel tube, the inner one filled with damping fluid. There are four spring loaded wheels fitted at the outer casing of the inclinometer to slide in a square aluminium pipe smoothly. The strain gauges fixed on the spring pendulum are connected through a PVC coated 4 core wire, the length of which depends upon the depth up to which horizontal movement of soil is to be recorded.

The instrument is used for measuring the lateral movement of the soils as well as in bracing system.

701:62. Magnetic extensometer

(RDSO, Lucknow—Min. of Rly.)

The instrument is used for measuring settlement of heave at different depths below ground level. It consists of a plastic plug with top cover screwed tightly in which hard ferrite material ring is housed. Three stiff springs are fixed on the plastic plug to anchor it properly at the required depth where measurement of vertical-movements of the soil are to be taken. In order to locate the position of the plug at different intervals, a metallic probe fitted with reed switch is used which when comes in the field of magnet completes the circuit and an indication is given at the top of the bore hole by ammeter or by an electrically worked audio device.

701:63. Electro spot steel identification kit—"Metaspot"

(CSIO, Chandigarh—CSIR)

Properties and applications of various alloys depend upon their alloying elements. To identify and estimate the constituent elements conventional methods of chemical analysis, instrumental techniques, etc., are costly, time consuming and mostly destructive. Metaspot is useful for determining various alloy elements like carbon, chromium, manganese, nickel, tungsten, cobalt, molybdenum and vanadium present in steels. All the materials/components are available indigenously.

701:64. Projection attachment to vickers hardness tester

(CSIO, Chandigarh—CSIR)

The device is used for obtaining the vickers hardness of light sheet metals and their alloys. The Institute has developed 5X, 10X and 20X projection attachments with 7X projection eye piece. Normal optical and mechanical workshop facility will be enough to fabricate the device.

701:65. Water current meter

(CIFT, Cochin—ICAR)

The device is used for the measurement of water current in ocean, esturies and rivers. Water current range is 0 to 400 cm/sec and its depth range is up to 500 metres.

The device operates on 9 volts and cost of production per unit is about Rs.15,000.

701:66. Environmental data acquisition system

(CIFT, Cochin—ICAR)

Research institute has developed a system for collecting the data such as water level, water temperature, water salinity, water current and direction, relative humidity, rain and solar radiation etc. Cost of production is about Rs.25,000 to Rs.50,000 per unit depending upon the number of the parameters incorporated in the device.

701:67. High power coaxial triodes 5 KW and 12.5 KW
(CEERI, Pilani—CSIR)

These triodes are general purpose three electrode tube designed specially for induction and dielectric beating and AM broadcasting.

SEU is 50 Nos. of 12.5 kW and 60 Nos. of 5 kW power triodes.

The fixed capital on plant is Rs.10 lakhs and the working capital required is Rs.2.7 lakhs. The approximate cost of production is Rs.10,000 for 12.5 KW and Rs.7,000 for 5 KW.

701:68. Digital turbidity meter
(CSIO. Chandigarh—CSIR)

The device is used for the measurement of turbidity of water samples in water pollution studies in the range of 0-1000 JTU. A modulated collimated beam of light is generated which when passing through water sample gets attenuated. This attenuation is detected by a sensitive photodiode & electrical signal from photo diodes are processed & displayed.

701:69. High/low impedance piezoelectric accelerometers
(ARDE, Pune—DRDO)

The device is used for the measurement of acceleration, velocity, displacement and preventive maintenance of machinery. The device is based on quartz and piezoelectric materials.

701:70. Electro spot testing kit for ferrous and non-ferrous alloys
(CSIO, Chandigarh—CSIR)

The kit is used for qualitative and semiquantitative detection of various elements present in steels, aluminium base and copper base alloys except silicon in aluminuim base and tin in copper base alloys.

Following processes are also available for licensing:

1. **All glass distillation apparatus**
   (NPL, New Delhi—CSIR)

*2. **Probes for ultrasonic flow detector for non-destructive testing (viz. normal probes, angle beam probes and surface wave probes)**
(NPL, New Delhi—CSIR)

*3. **Ultrasonic interferometer for velocity measurements**
(NPL, New Delhi—CSIR)

*4. **Bent crystal X-ray spectrograph**
(NPL, New Delhi—CSIR)

*5. **Linear mechanical drive for a Mossbauer spectrometer**
(NPL, New Delhi—CSIR)

*6. **Sensitized zinc oxide paper for electrophotographic machines**
(NPL, New Delhi—CSIR)

7. **Three dimensional panoramic photographic display**
   (NPL, New Delhi—CSIR)

8. **X-ray topographic equipment along with microfocusing X-ray generator**
   (NPL, New Delhi—CSIR)

*9. **Liquid crystal thermal devices**
(NPL, New Delhi—CSIR)

*10. **Vacuum leak detector**
(NPL, New Delhi—CSIR)

*11. **Therapeutic/diagnostic unit**
(CSIO, Chandigarh—CSIR)

*12. **Prismatic binocular**
(CSIO, Chandigarh—CSIR)

13. **Polarizing microscope**
    (CSIO, Chandigarh—CSIR)

*14. **Focimeter**
(CSIO, Chandigarh—CSIR)

15. **Glass blowing equipment**
    (CSIO, Chandigarh—CSIR)

*16. **Digital frequency meter**
(CSIO, Chandigarh—CSIR)

*17. **Digital pH meter**
(CSIO, Chandigarh—CSIR)

***18. Digital panel meter**
(CSIO, Chandigarh—CSIR)

***19. Solidstate constant temperature**
(NAL, Bangalore—CSIR)

***20. Digital clock**
(CSIO, Chandigarh—CSIR)

***21. High voltage regulated power supply**
(CSIO, Chandigarh—CSIR)

22. Focometer
(CSIO, Chandigarh—CSIR)

***23. Foetus stethoscope**
(CSIO, Chandigarh—CSIR)

***24. Ear microscope**
(CSIO, Chandigarh—CSIR)

***25. Patient monitor system**
(CSIO, Chandigarh—CSIR)

26. Thread counter (microscope type)
(CSIO, Chandigarh—CSIR)

27. Cloth density meter
(CSIO, Chandigarh—CSIR)

28. Hypospray jet injector
(IRDE, Dehradun—DRDO)

***29. Various lens system**
(CSIO, Chandigarh—CSIR)

***30. Bubble chamber scanner**
(CSIO, Chandigarh—CSIR)

***31. Digital tachometer**
(CSIO, Chandigarh—CSIR)

32. Thermo-emf current converter
(CSIO, Chandigarh—CSIR)

33. EMF voltage/current transmitter
(CSIO, Chandigarh—CSIR)

34. Suppressed zero voltmeter
(CSIO, Chandigarh—CSIR)

35. 20-Channel temperature logger
(CWPRS, Pune)

36. 20-Channel digital data logger using commercial typerwriter
(CWPRS, Pune)

37. 20-Channel logger for water speed measurement
(CWPRS, Pune)

38. Transistorised capacitance wave height recorder
(CWPRS, Pune)

***39. Water level monitor**
(CWPRS, Pune)

40. Pressure transducer
(CWPRS, Pune)

41. Telemetry system for data transmission & acquisition
(CWPRS, Pune)

***42. Solidstate analogue current meter**
(CWPRS, Pune)

***43. Water surface follower**
(CWPRS, Pune)

***44. Minicurrent meter for water flow/speed measurement**
(CWPRS, Pune)

45. Solidstate inverters
(LRDE, Bangalore—DRDO)

46. Volume change measuring device
(CBRI, Roorkee—CSIR)

47. Solar water heater, large size and domestic size
(CBRI, Roorkee—CSIR)

***48. Direct reading spectrophotometer/calorimeter**
(NCL, Pune—CSIR)

***49. DC recording polarograph**
(NCL, Pune—CSIR)

50. Tool makers microscope
(Madras Dial Gauge & Measuring Instruments, Bangalore)

***51. Vibration generator (Type VG II) with power amplifier**
(NAL, Bangalore—CSIR)

***52. Resistance strain gauges**
(NAL, Bangalore—CSIR)

***53. Resistance strain gauges**
(NAL, Bangalore—CSIR)

54. **Wow and flutter meter**
(AIR, New Delhi—Min. of Information and Broadcasting)

*55. **Ultrasonic hardness tester**
(CSIO, Chandigarh—CSIR)

56. **Autocollimator**
(CSIO, Chandigarh—CSIR)

57. **Desert desalting kit**
(DL, Jodhpur—DRDO)

*58. **Carbon monoxide detector tubes**
(CMRS, Dhanbad—CSIR)

*59. **Cable fault locator**
(CMRS, Dhanbad—CSIR)

60. **Hydrogen sulphide detector tubes**
(CMRS, Dhanbad—CSIR)

*61. **Catalyst filaments for methanometers**
(CMRS, Dhanbad—CSIR)

62. **Built-in storage type solar water heater**
(Central Arid Zone Research Institute, Jodhpur—CSIR)

*63. **DC/AC polarographs**
(NAL, Bangalore—CSIR)

*64. **Gas chromatograph**
(BARC, Bombay)

65. **Plasma cutting torch**
(BARC, Bombay)

*66. **Dissolved oxygen analyser**
(CSIO, Chandigarh—CSIR)

67. **Universal preparative attachment for gas chromatograph**
(RRL, Jorhat—CSIR)

68. **Electronic torque wrench**
(NAL, Bangalore—CSIR)

69. **Water testing field kit**
(Defence Laboratory, Jodhpur—DRDO)

70. **External demand pacemaker**
(CSIO, Chandigarh—CSIR)

71. **Portable acidity testing kit for transformer oil**
(CPRI, Bangalore)

72. **Universal ultrasonic generator**
(RRL, Bhubaneswar—CSIR)

73. **Radio frequency generator and probe for ultrasonic therapy unit**
(RRL, Bhubaneswar—CSIR)

74. **Portable warp load meter**
(CIFT, Cochin—ICAR)

75. **Trawl depth meter**
(CIFT, Cochin—ICAR)

*76. **Cardiac pacemaker**
(DEBEL, Bangalore—DRDO)

*77. **Cardiac care system**
(DEBEL, Bangalore—DRDO)

*78. **Phono-cardiograph**
(DEBEL, Bangalore—DRDO)

*79. **Apparatus electrosleep**
(DEBEL, Bangalore—DRDO)

80. **Electro-magnetic blood flow meter**
(AIIMS &IIT, New Delhi)

*81. **Electrical impedance plethysmograph**
(AIIMS & IIT, New Delhi)

82. **Heart rate telemetry**
(IIT & AIIMS, New Delhi)

*83. **Overhead projector**
(IIT, New Delhi)

84. **Remote indicating load cell**
(CMRS, Dhanbad—CSIR)

85. **Remote indicating hydraulic load cell**
(CMRS, Dhanbad—CSIR)

86. **Low cost solar geyser**
(CBRI, Roorkee—CSIR)

87. **Permanent magnet moving coil frequency meter**
(NSIC, New Delhi)

88. **Mobility aid for blind**
(NPL, New Delhi—CSIR)

*89. **Scanning lens system for electrofax type of copying machine**
(CSIO, Chandigarh—CSIR

90. **Electronic artificial voice restorer**
(Individual inventor)

91. **Multipurpose solvent extractor**
(NPL, New Delhi—CSIR)

92. **Solidstate distortion and noise level monitor**
(AIR, New Delhi—Min. of Information & Broadcasting)

93. **Interference objective**
(CSIO, Chandigarh—CSIR)

94. **Multitest instrument**
(CSIO, Chandigarh—CSIR)

95. **Relaxometer**
(Command Hospital, Calcutta—DRDO)

96. **Solidstate amplitude modulation monitor**
(AIR, New Delhi)

97. **Solidstate 12″-110°, multi-channel TV receiver**
(AIR, New Delhi—Min. of Information & Broadcasting)

98. **Thermal dilution cardiac output device**
(IIT, New Delhi)

99. **TV receiving aerials**
(AIR, New Delhi)

*100. **Electron microscope grids**
(IIT, New Delhi)

*101. **Piezoelectric vibration pick-ups (Accelerometer)**
(CEERI, Pilani—CSIR)

102. **Amplitude modulation monitor for use with medium wave and short wave transmitters**
(AIR, New Delhi—Min. of Information and Broadcasting)

103. **Digital master clock system**
(AIR, New Delhi—Min. of Information and Broadcasting)

104. **Schlieren apparatus**
(CMRS, Durgapur—CSIR)

105. **Aligned micro episcope**
(Ramakrishna Mission Vidyapith, Purulia)

106. **Prismatic binocular**
(IRDE, Dehradun—DRDO)

*107. **Automatic charger for lead acid batteries**
(NAL, Bangalore—CSIR)

108. **Electroless tin plating bath for printed circuit boards**
(NAL, Bangalore—CSIR)

109. **Altimeter**
(CSIO, Chandigarh—CSIR)

110. **Direct reading mechanical dilatometer**
(CSIO, Chandigarh—CSIR)

111. **Magnetic particle clutch**
(MERADO, Pune—CSIR)

112. **Porosimeter**
(NGRI, Hyderabad—CSIR)

113. **Solidstate power factor meter**
(Institute for Design of Electrical Measuring Instruments, Bombay—Min. of Industry & Civil Supplies)

114. **Solidstate frequency meter**
(Institute for Design of Electrical Measuring Instruments, Bombay—Min. of Industry & Civil Supplies)

115. **Solidstate current meter**
(Institute for Design of Electrical measuring Instruments, Bombay—Min. of Industry & Civil Supplies)

*116. **Ophthalmoscope**
(CSIO, Chandigarh—CSIR)

117. **Integrated circuit functional tester**
(CSIO, Chandigarh—CSIR)

118. **Programmable digital IC tester**
(CSIO, Chandigarh—CSIR)

119. **Optical system for facsimile equipment**
(CSIO, Chandigarh—CSIR)

120. **Pipe and cable locator**
(CSIO, Chandigarh—CSIR)

121. **Digital optical density meter**
(CSIO, Chandigarh—CSIR)

*122. **50 MHz counter-timer**
(CSIO, Chandigarh—CSIR)

123. **Ophthalmometer**
(CSIO, Chandigarh—CSIR)

124. **Industrial vacuameter**
(NPL, New Delhi—CSIR)

125. **Direct reading current meter**
(NPOL, Cochin—DRDO)

126. **Cryo-probe machines for eye surgery**
(NPL, New Delhi—CSIR)

127. **Sequential temperature recorder**
(NAL, Bangalore—CSIR)

*128. **Capacitance type displacement measuring transducer and associated signal conditioner Type A and B**
(NAL, Bangalore—CSIR)

*129. **High current potentiostat**
(NAL, Bangalore—CSIR)

130. **Electronic dust precipitator using corona discharge**
(NPL, New Delhi—CSIR)

131. **Shallow electromagnetic prospecting unit (metal detector)**
(NGRI, Hyderabad—CSIR)

*132. **16 mm cine projection lens**
(CSIO, Chandigarh—CSIR)

*133. **Echoencephaloscope**
(CSIO, Chandigarh—CSIR)

*134. **Digital temperature lineariser**
(CEERI, Pilani—CSIR)

135. **Composite device to measure differential settlement, tilt and crack width in building**
(CRRI, New Delhi—CSIR)

136. **Filament winding machine**
(NAL, Bangalore—CSIR)

137. **Voltage regulated power supply**
(CEERI, Pilani—CSIR)

*138. **X-ray image intensifier closed circuit television system**
(CSIO, Chandigarh—CSIR)

139. **AM/FM receiver**
(AIR, New Delhi—Min. of Information & Broadcasting)

140. **Automatic recording system for direct and tri axial shear apparatus**
(CWPRS, Pune—Ministry of Power)

141. **Moisture meter**
(CIFT, Cochin—ICAR)

142. **Foam level controller**
(CSIO, Chandigarh—CSIR)

143. **Monitor DC defibrillator**
(CSIO, Chandigarh—CSIR)

*144. **Digital temperature indicator**
(CSIO, Chandigarh—CSIR)

*145. **Digital grain moisture meter**
(CSIO, Chandigarh—CSIR)

*146. **Thermo silico tester**
(CSIO, Chandigarh—CSIR)

147. **Digital sound level meter**
(CEERI, Pilani—CSIR)

148. **Acoustic anisotropy apparatus**
(NGRI, Hyderabad—CSIR)

149. **Rotor induction water current meter**
(NIO, Goa—CSIR)

150. **Tide and wave telemeter**
(NIO, Goa—CSIR)

151. **In-situ temperature and salinity meter**
(NIO, Goa—CSIR)

ELECTRICAL INDUSTRY

CODE 800

*801:1. Cinema arc carbons

(NPL, New Delhi—CSIR)

These arc carbon electrodes between which arcs are struck for producing high intensity illumination required for projecting motion pictures. The process for cinema arc carbons developed on a pilot plant scale at NPL uses indigenous raw materials and equipment. Minimum economic capacity is 6,000 pairs per day.

*801:2. Lead acid storage batteries

(CECRI, Karaikudi—CSIR)

Lead acid batteries find application in motor cars, trucks and similar vehicles for the purpose of starting, lighting, and ignition. The battery developed is based on the raw materials available indigenously and it conforms to IS: 395-1962.

801:3. Sac cell using aluminium alloy anode

(CECRI, Karaikudi—CSIR)

Sac cell with aluminium alloys as an anode and modified electroylte can be used as a substitute for Leclanche type sac cells. These cells are used by the Indian Railways for operating block instruments, telephone and signals. SEU for the industry is for the production of 2,00,000 aluminium alloy rods per year.

801:4. Calcium tungstate (blue phosphor)

(CECRI, Karaikudi—CSIR)

Calcium tungstate (blue phosphor) finds application mainly in the fluorescent tube light industry. The process developed envisages mixing of calcium oxide containing substance (such as calcium carbonate) and tungstic oxide containing substance such as tungstic acid in finely divided state. SEU for this industry is 5 tonnes per annum.

*801:5. Demagnetiser of rail joints

(NPOL, Cochin—DRDO)

Metal arc welding of rails is a new process being adopted by Indian Railways for welding of rail joints. The Institute has developed a demagnetiser for demagnetising rail joints in-situ during the metal arc welding so that the magnetism of the rail will not hamper the welding process.

*801:6. Sealing glass for glass to metal seals

(CGCRI, Calcutta—CSIR)

These glasses are used or production of glass to metal seals viz. transistor headers. It is used for sealing glass tubes, rods, bulbs, frits, sintered perform etc. with metals and alloys. SEU is 7 tonnes/annum.

801:7. Cadmium selenide photo conductive cell

(CECRI, Karaikudi—CSIR)

The developed cell converts the varying intensities of light into varying intensities of electric currents by the application of certain voltage to it. These photoconductive cadmium selenide cells have a light sensitivity to the visible radiation and find use on electronic musical computers, recorders, choppers and photo-electric circuits. SEU is 30,000 cells per annum.

801:8. Mercury oxide cell

(CECRI, Karaikudi—CSIR)

Mercury cells originally designed for specific defence purpose are fast entering the common markets in Western countries. These cells have certain exclusive properties such as steady voltage and long shelf life which other rival battery systems cannot claim. The process developed at CECRI obviates many disadvantages. SEU for mercury oxide cells (a) search becon battery, (b) instrument battery, (c) grid bias battery is for manufacturing 1000, 1500 and 9000 cells per year respectively.

801:9. Calcium holophosphate daylight phosphor

(CECRI, Karaikudi—CSIR)

Calcium holophosphate daylight phosphor finds application in the manufacture of fluorescent tube lights. The process developed broadly involves the solidstate reaction of high purity raw materials of fine particle size at a high temperature. An advantage of the process is that the good phosphor could be prepared even without the use of special gas atmosphere. SEU for the industry is the production of 3 tonnes of the product per annum.

801:10. Manufacture of low wear carbon brushes from metal graphite brushes

(NPL, New Delhi—CSIR)

Carbon brushes are widely used in electrical machinery and automobiles industry. A new process on low wear carbon brushes from metal graphite brushes has been developed at the Institute. The fixed capital for a plant of 10 tonnes per annum is estimated at Rs.3 lakhs, cost of production is expected to be Rs.90,000 per tonne.

Following processes are also available for licensing:

*1. **Midget electrodes**
(NPL, New Delhi—CSIR)

*2. **Silver tungsten tablets**
(NPL, New Delhi—CSIR)

*3. **Synthetic optical crystals of alkaline earth fluorides**
(NPL, New Delhi—CSIR)

*4. **Silver powder and conducting ink**
(CECRI, Karaikudi—CSIR)

*5. **Ceramic magnets**
(NML, Jamshedpur—CSIR)

*6. **Alnico type permanent magnet alloys**
(NML, Jamshedpur—CSIR)

7. **Fibre glass epoxy based etched copper terminals by manual process**
(NAL, Bangalore—CSIR)

8. **Nickel clay and cadmium clay,**
(LRDE, Bangalore—CSIR)

9. **Electrical relay tester**
(CMRS, Dhanbad—CSIR)

ELECTRONICS INDUSTRY

CODE 900

900:1. 16-Bit fractional binary to 4 digit decimal converter

(CEERI, Pilani—CSIR)

This converter shows applications of logic gates, flipflops, latches, decoders and display tubes. The present form of converter is suitable for educational institutes engaged in teaching digital circuits. SEU is 100 units/annum.

900:2. Telephone conference facility

(CEERI, Pilani—CSIR)

This is a device meant to provide the facility of a telephone conference within an organisation, making it easy for the executives and managers to confer without work disruption. The device is simple to operate, light in weight, small in size and easy to instal on the internal telephone exchange and does not require any power supply, this can provide conference facility among a maximum of 5 persons connected to the same internal telephone exchange.

*900:3. Hard ferrites

(NPL, New Delhi—CSIR)

Hard ferrites are barium ferrites having hard magnetic properties, and are used as magnets for toy motors, soap saver, pin cushions, etc. The basic raw materials ferric-oxide, barium carbonate are mixed in definite proportion with minor additives like lead oxide in a ball mill and dried in an oven.

***900:4. Microwave components for portable radars comprising of coaxial circulators, waveguide to coaxial adapters and cowave circulators**

(DLRL, Hyderabad—DRDO)

Circulators are used as duplexers in transponders and isolating devices in low noise RF amplifiers which are employed as front ends in microwave receivers to improve the sensitivity performance.

***900:5. Soft ferrites**

(NPL, New Delhi—CSIR)

Soft ferrites are materials which do not retain magnetism but provide an easy magnetic path with low loss especially at high frequencies. Process developed in for the manufacture of linear as well as non-linear soft ferrites. The raw materials, ferric oxide, nickel carbonate, ceramics, etc., are mixed in definite proportion with minor additives.

900:6. UHF airborne sleeve antenna (225-400 MHz)

(DLRL, Hyderabad—DRDO)

The device is used with equipment for ground communication. It is basically a monopole above ground plane and consists of two parts connected together by coaxial stub. A matching section is introduced to make the antenna broad-band.

900:7. Film processing apparatus

(ICMR, Delhi)

It is used for processing colour or black and white films. The apparatus consists of a chamber having a plurality of compartments adapted to each stored solution for the processing of the film, temperature control unit and agitator for agitating the solutions.

900:8. Microprocessor based electronic telephone exchange

(CEERI, Extension Centre, New Delhi—CSIR)

Microprocessor based EPAX system is primarily for internal communications having the basic features of manual or electro mechanical exchanges. In addition, it possesses features which are unique and made possible by using microprocessor, semi-conductor, logic gates and memory devices to control the sequence of operation. The actual links between the subscribers are established through electro-machanical reed relays. The special features of exchange are: (i) conferencing between the subscribers, (ii) automatic dial, ring and busy tone shut off, and (iii) call storage—at any instance if the called party is engaged and the caller holds on until the called party is free, the ring tone goes to the party directly without dialing again. Type of telephone is ITI Rotary dial. Power consumption 90 watts.

900:9. Hybrid microcircuits-thick film

(CEERI, Pilani—CSIR)

The fabrication of thick film hybrid microcircuits is based on the techniques of screen printing conductive, dielectric and resistive pastes on to alumina (90%) substrates. These pasters when fired at temperatures in the range of 800°C to 1000°C become an integral part of the ceramic and form the basic structure of an electronic circuit. Out of tolerance resistors can be trimmed to desired values within 1% accuracy or better using air abrasive or laser methods. Also where circuit functions is of prime importance compared to specific resistance value and tolerance, functional trimming is utilised.

900:10. 5 kW and 12.5 kW coaxial power triode

(CEERI, Pilani—CSIR)

Power triodes for induction and dielectric heating and AM broadcasting have been developed. These tubes feature coaxial electrode structures and have several advantages like low lead inductance, higher operational frequency etc. over the conventional type. These tubes are particularly suitable for cathode drive operation.

900:11. Automatic centralised industrial temperature indicating & monitoring system with control status indicator

(CEERI, Pilani—CSIR)

The system developed consists of (i) precision 4½ digit system grade industrial temperature indicator, (ii) low thermal scanner—multiplexer, (iii) 24-point indicating and monitoring panel, and (iv) control-status-indicator. The system can be used in any process industry to monitor various process temperature points accurately.

900:12. Glass electrodes for pH, pNa and pK measurement

(CGCRI, Calcutta—CSIR)

Institute had developed glass electrodes for pH measurement and ion selective electrodes for correct estimation of soda and potash.

900:13. Blood capillary pH electrodes and blood pCO_2 electrodes for anaesthesia monitoring equipment

(CGCRI, Calcutta—CSIR)

These electrodes are used for the measurement of blood pH and pCO_2 in anaesthesia monitoring equipment required in medical electronics. These electrodes are not being manufactured in our country and demand is met by import only.

900:14. Single channel refraction seismic timer

(NGRI, Hyderabad—CSIR)

The device is used for the measurement of seismic wave velocities at a given place. The data obtained can be used to evaluate the subsurface geologic information up to depths of 15 metres.

900:15. Compensated ultrasonic timer technique

(NGRI, Hyderabad—CSIR)

The compensated ultrasonic timers are used for measuring wave velocity in rocks and other materials. It is essentially a digital method unlike the earlier analogue methods.

900:16. Monochrome television picture tube phosphor

(NPL, New Delhi—CSIR)

Institute has developed a process on pilot plant scale for production of pure sulphides of zinc and cadmium and their phosphors for use in TV picture tubes, solar cells and optoelectronic devices. The capacity of the pilot plant set up is 1.8 tonnes/year on three-shift basis. The country will save about Rs.2 million in foreign exchange when indigenous production starts.

900:17. Micro manometer

(NAL, Bangalore—CSIR)

The device is used to measure very low pressures (as low as 0.01 mm water head) accurately and with minimum interaction with the incoming pressure. The manometers available in the country are not capable of measuring such a low pressure.

900:18. Auto leveller

(IJIRA, Calcutta)

The Research Association has developed an auto leveller for automatic controlling of the silver grist for improved spinning performance and control of yarn count. The grist of the silver is sensed at the delivery of the machine and the draft is varied automatically so that the grist of the outgoing silver is maintained at a constant level.

900:19. Activation of dielectric substrate for electrolysis deposition of metals

(IIT, Bombay)

This new process replaces stannous chloride used in the conventional process by a solution of alkali metal hypophosphite. The Institute has developed the process to improve the adhesive strength of copper deposited by electrolysis and electroplating procedures.

900:20. Bollard pull monitor

(CIFT, Cochin—ICAR)

The device is used for measure the power delivered by marine engines. This is needed for precise testing of marine engines in field condition. At present this instrument is imported and most occasions the demand is met with improvised methods.

900:21. Electronic speed and distance log
(CIFT, Cochin—ICAR)

The device is used for the measurement of speed and distance travelled by vessels, boats and ships. The range of the device is 0 to 12 knots and accuracy is ± 0.2 knot.

Following processes are also available for licensing:

CEERI, Pilani—CSIR

***1. Silicon planar transistor**
***2. TV camera**
***3. TV video monitor**
***4. TV video pulse distribution amplifier**
***5. Varactor diodes**
6. Precision 4½ digit thermometer
7. Video sweep generator
8. Electronically tuned multichannel booster amplifier for TV receivers—Band I & III
9. Electret condenser microphone
***10. VHF attenuator**
11. VHF multichannel TV tuner
12. Desoldering bits for IC packages and sockets

NPL, New Delhi—CSIR

***13. Electrostatic photocopying machine**
***14. Microwave components**
***15. Fabrication and reconditioning cathode ray tubes and television picture tubes**
***16. Piezoelectric materials and bimorph elements**
***17. Ultrasonic transducer**
18. Electrofax photocopying machine using sensitized zinc oxide paper
19. Broad band ferrites resonance isolators for microwave application
20. Electronic secretary
21. Large precision pipette

CSIO, Chandigarh—CSIR

22. Projection system 20X
***23. Electronic information display board**
***24. Electromagnetic flow meter**
25. Dark room camera objective—457 mm, f/10
26. Wide angle optical systems.

IIT, Madras

27. Thyristor controller for 2-quadrant DC motor drive
28. Thyristor controller for 4-quadrant DC motor drive
29. Speed controller for a slipring induction motor using a thyristor inverter
***30. Digital panel meter**
(NAL, Bangalore—CSIR)

***31. Demonstration boards for electronic circuits**
(TTTI, Madras—Min. of Edu. & Soc. Welf).

32. 'X' Band wave guide circulator and isolators
(DLRL, Hyderabad—DRDO)

33. Interferometric fibre stapler
(CTRL, Bombay—ICAR)

***34 Optical printer**
(ICMR, New Delhi)

MISCELLANEOUS INDUSTRIES

CODE 1000

***1000:1. Diagnostic strips for testing albumin in urine**
(DMSRDE, Kanpur—DRDO)

These strips can be used for the quantitative detection of albumin in urine. The process consists of dipping paper strips in a specially prepared reagent solution. The treated strips are then dried.

***1000:2. Electrochemical marking of metals**
(CECRI, Karaikudi—CSIR)

A know-how for the electrochemical marking of metals so that metal articles of industry and commerce are marked for the purpose of identification, certificate of quality and for advertisement has been developed.

***1000:3. Precipitated silica**
(CSMCRI, Bhavnagar—CSIR)

Precipitated silica finds applications in textile printing ink, polishes, carriers, tooth paste and as rheological control additives in PVC pastes etc. The product can successfully replace imported fine quality silica. Sodium silicate, commercial hydrochloric acid, aluminium sulphate and lime are the raw materials.

***1000:4. Stable gel for hot and cold sachets**
(NCL, Pune—CSIR)

The invention relates to the manufacture of stable gel which may be filled and hermetically sealed in plastic sachets or small bags to serve as thermal reservoirs of heat or cold.

***1000:5. Casting pit refractories of bloating type**
(CGCRI, Calcutta—CSIR)

Casting pit refractories are required for producing ingot steels. At present non-bloating type of refractories are used which are not very satisfactory. The process consists of pulverizing ferruginous clay and certain other allied materials and preparing grog by calcination from this composition. Casting pit refractories of any shape or size can be prepared by this method. SEU is 20,000 tonnes per year.

1000:6. Pour point depressant
(IIT, Bombay)

This is used as an additive. Diesel oil, lubricating oil, turbine oil etc. which are of high pour point when blended with 0.2 to 0.8% by weight of the additive can depress the pour point of the oil by 15° to 25°C. The SEU for this process is one tonne per day.

1000:7. Special charcoal blocks used in polishing metal surfaces
(CFRI, Dhanbad—CSIR)

The process is very simple. The wood available indigenously is cut to desired size according to the requirements of the consumer. The wood pieces are then carbonized in externally heated metallic retorts and the evolved gases are cooled in a condenser to separate the liquid products namely tar and liquor and the stripped gas is collected in a gas holder and is used as a fuel. From the liquid products, a number of chemicals, viz. wood preservatives, methyl alcohol, acetic acid, etc. can be made. The charcoal block produced by this process is of a special nature and is suitable for polishing metal surfaces.

The capital investment of a plant producing 800 kg per year of special charcoal blocks based on 300 working days in a year and 3 shifts operation is estimated to be Rs.20,000.

***1000:8. Briquetting of charfines to obtain shaped smokeless domestic fuel**
(RRL, Hyderabad—CSIR)

As the name suggests, it is used as domestic fuel in domestic ovens. It can easily substitute coke, wood, charcoal, kerosene, and check the increasing consumption of LPG which is based on imported crude. Capacity for SEU of this process is 10 tonnes per hour of LT charfines input. The investment required for this capacity is Rs.130 lakhs, excluding the cost of building, plant and machinery structurals and platforms. The plant will be a part of the main LTC plant or other carbonisation plant where infrastructural facilities are available.

***1000:9. Disposable breathing mask**
(Central Labour Instt., Bombay)

Disposable breathing masks can be used by workers exposed to dust hazards and as such will be useful in the cement plants, stone quarries, textile industry, etc. The developed mask gives better filtering efficiency and low resistance to breathing.

The investment reuired to put up a unit for producing 2,40,000 pcs. per annum has been estimated at Rs.2.09 lakhs.

1000:10. Glass enamels/glass colours
(CGCRI, Calcutta—CSIR)

CGCRI, Calcutta, has developed a number of coloured glass enamels covering the principal shades usually used in industry in the firing range of 500-550°C. Glass enamels are used on glass surfaces for decorative and coloured effects on tableware, lighting fixtures, permanent marking and labelling of glass apparatus and beverage bottles. Good demand of the item is anticipated Capital outlay is Rs.3 lakhs for the manufacture of 50 kg of the material per day.

*1000:11. Refractory cement (Fondu Type)
(NML, Jamshedpur—CSIR)

Refractory cement commonly known as calciumaluminate cement is a base material for making refractory castables. The highest temperature service conditions recommended for such castable is of the order of 1350°C and under special cases with superior aggregates it can be used up to 1450°C. They find extensive application for making different types of shapes and lining various types of furnaces for ceramic and metallurgical industry.

*1000:12. Cordierite based saggars
(CGCRI, Calcutta—CSIR)

Saggars are used for firing ceramic wares in industrial kilns to protect the wares from the ill effects of direct firing. CGCRI, Calcutta, has developed saggars used in the pottery industry. This has a service life of 30 firing cycles compared to the service life of clay based saggers which is usually 5 to 6 firing cycles.

*1000:13. Potassium dichlorisocyanurate as a water sterilizing agent.
(DRDE, Gwalior—Mim. or Def.)

Potassium dichlorisocyanurate is used as a water sterilizing agent in the form of tablets. These tablets are used for chlorination of water for drinking purposes. Isocyanuric acid has been prepared by cyclization of urea. Chlorination of isocyanuric acid is carried out followed by neutralization with potassium hydroxide.

*1000:14. Acid inhibitor in solid form
(CECRI, Karaikudi—CSIR)

Acid inhibitor in solid form can be used for the inhibition of corrosion during acid pickling of ferrous items. The process is simple and consists in mixing three different chemicals in solid form and adding into the pickling bath in a proper concentration.

1000:15. Soak cleaning compound for steel contaminated with oil
(CECRI, Karaikudi—CSIR)

Soak cleaning compound is used for removing the mineral oils, vegetable oils and greases which are usually applied to ferrous surface for corrosion protection during transit and storage. It is essential to remove these oils and greases before painting. The process consists in mixing different constituents with water under stirred condition.

*1000:16. Portland cement coating for steel
(CECRI, Karaikudi—CSIR)

The new protective coating developed is based on portland cement and provides good protection to structural steel in salt laden atmosphere. Portland cement, inhibitor solution and water glass are the main raw materials required.

1000:17. Substitute for renovator web
(DRDE, Gwalior—DRDO)

A polish for renovating web kit has been developed. The product can be used by Army and Civil Security personnel for polishing olive green coloured web equipment. It can be used on school boys and water kits also.

1000:18. Palatable laxative from seed husk of psyllium
(CDRI, Lucknow—CSIR)

Isapgol husk is used as a laxative but it is disliked by people due to its blend taste. CDRI has developed a process of make it palatable and the product has good consumer acceptability. Apart from good demand in the country it has export potential also.

1000:19. Selective black nickel plating of solar collectors.

(CECRI, Karaikudi—CSIR)

Selective black nickel coating finds application in plating solar collectors used for solar energy applications. At present selective coatings are not reported to be used for commercial scale. CECRI has developed a process for the manufacture of selective black nickel plating for solar collectors. SEU for this industry is for putting up a plant having a capacity of 5000 sq. m. per year.

1000:20. Rescue and emergency care vehicle

(AIIMS, New Delhi—DST sponsored projects)

The Institute has developed a vehicle for transporting persons involved in any medical emergency (including cardiac emergency) normally encountered like multiple injuries, head injury, abdominal injury etc., to nearby hospital. The vehicle has been designed for easy manoeuvrability through rough terrains and narrow lanes in small towns. The vehicle is also suitable in urban areas as the specially designed stretcher will enable to bring a patient down the stairs in multi-storeyed buildings by one individual instead of four stretcher bearers. Facilities like power, water etc. and provision for all necessary medical equipment/stores have been provided in the design. With a built-in wireless communication system, the vehicle can provide service to an area within a radius of 10 kms from the nearby hospital. At present similar vehicles are being imported or received as gifts from other countries. But these are not suitable for Indian conditions.

1000:21. Agrowaste compaction machine

(SAR, Sangli)

To utilise agricultural wastes like saw dust, groundnut shells, bagasse, bamboo dust, straw etc. efficiently the waste have to be in compacted form. The agrowaste compaction machine has been developed by SAR in collaboration with NRDC to briquette all the agricultural waste without using any binder. The machine is available in three different designs viz. manually operated, bullock operated and power operated with capacities of 50 kg, 150-200 kg and 250 kg respectively, of briquetted fuel per day of 8 hours.

*1000:22. Dimethylaniline (DMA)

(NCL, Pune —CSIR)

Dimethylaniline is an important intermediate used in the dyestuff industry. It is also used for the manufacture of tetryl. Aniline is reacted with methanol at moderate temperature and pressure in the presence of a catalyst. The yield is 96.97% SEU for this product is 600 tonnes per annum.

1000:23. Potassium nitrate from potash salt and nitric acid

(CSMCRI, Bhavnagar—CSIR)

Potassium nitrate is utilised in the manufacture of gun powder and fireworks. The process gives the product which meets IS specification and comparatively less energy is required. The raw material required are potassium sulphate, lime stone and nitric acid. For setting up a plant having 1 TPD capacity the project cost has been estimated at Rs.12 lakhs (1984).

1000:24. High strength plaster of Paris

(CSMCRI, Bhavnagar—CSIR)

High strength plaster of Paris (Alpha plaster) has specific uses in the preparation of Jigger moulds in the ceramic industry, as building blocks and partition wall. Alpha plaster is having compressive strength almost four times than that of Beta plaster. Marine gypsum, maleic anhydride and sodium hydroxide are the raw materials. A plant having 10 TPD capacity is estimated to cost Rs.13.12 lakhs (1984).

1000:25. Improved hurricane lanterin

(IIP, Dehradun—CSIR)

IIP, Dehradun has developed an improved hurricane lanterin which gives more light and efficiency than existing model at no extra cost. The cost of the lanterin is estimated to cost Rs.10 per unit.

1000:26. Epsom salt from sea bittern

(CSMCRI, Bhavnagar—CSIR)

Epsom salt (magnesium sulphate) finds applications in tanning of leather and dyeing of textile. CSMCRI, Bhavnagar, has developed a novel process for the manufacture of epsom salt using sea bittern as raw material. A plant having capacity of 5 TPD has been estimated to cost Rs.14 lakhs (1984).

1000:27. Hand lay up technique for moulding of banana fabric polymer composite products

(RRL, Trivandrum—CSIR)

The process developed using natural fibre is likely to substitute glass fibre. The product can be used as laminates and protective covers, mirror casing, voltage stabilizer, boxes etc. The SEU for this industry is 7,500 units/annum or 4,500 kg/annum and having a capital investment of Rs.2.07 lakhs (1984). This excludes the cost of land and building.

1000:28. SCR control unit for automated cathodic and anodic protection

(CECRI, Karaikudi—CSIR)

The device will find application in all anodic/cathodic protection installations in chemical industries, power plants, protection of pipe lines carrying oil and water. Research Institute has fabricated three units (5A/50V, 20A/50V and 50A/50V). SEU is 300 Nos. and investment required is Rs.1.80 lakhs. Cost of production for 5A/50V is Rs.1,250, 20A/50V is Rs.1,600 and 50A/50V is Rs.2,200.

1000:29. Fire retardant PVC cloth

(IIS, Bangalore—DST project)

PVC cloth is used for various purposes like seat covers, tent materials, etc. In order to impart fire retardancy characteristics to PVC cloth, a process has been developed for producing phosphorus based polymeric resin which could be used for coating PVC cloth. The coated cloth is more stable to leaching during washing and meets the flamability test requirement as per ISI/259/84. Conventional reactor for polymerisation with arrangement for reduced pressure distillation could be used for producing the resin.

1000:30. Sterilizing outfit for use with water bottle for snow bound areas

(DL, Jodhpur—DRDO)

The outfit is used to sterilize as well as mineralise the water obtained from streams, rivers and melting snow in hilly area. The outfit consists of sterilising tablets and thiomineral tablets. Composition of these tablets is based on the detailed chemical and bacteriological analyses.

1000:31. Insulating bricks from rice husk ash

(CGCRI, Calcutta—CSIR)

CGCRI has developed insulating bricks from rice husk ash which can be used for insulation of all types of industrial furnaces, particularly ceramic kilns and furnaces in steel and cement plants as well as in non-ferrous and petro chemical industries. The item has a good demand. Thermal conductivity at 1000°C is 00004267 gm cal sec^{-1} cm^{-2} deg^{-1} CCm. Capital cost is Rs.8.7 lakhs for a plant of capacity 1.5 lakhs bricks per year.

1000:32. Glass reinforced gypsum composite boards

(CGCRI, Calcutta—CSIR)

CGCRI, Calcutta, has developed glass reinforced gypsum boards which can be used as partial substitute for wood. Raw materials for the process are plaster of Paris and glass fibres in the form of rovings. GRG panels can be used for making door panels, false ceilings, partitions, furniture etc. CC for a plant of capacity 12,000 panels per annum of size (2000×1000×6 mm thick) is Rs.17.2 lakhs.

1000:33. Inhibitor suitable for pickling of steels in hydrochloric acid solution

(NML, Jamshedpur—CSIR)

Ferrous metals when formed into steel sheets, plates, bars etc. are subjected to high temperatures which results in the formation of a coating of iron oxide on the metal surface without affecting single fibre strength are removed by acid pickling. Capital cost is Rs.6.4 lakhs for a plant of capacity 100 litres per day of the inhibitor.

1000:34. Celluloid coated rayon/cambric sheet

(ERDL, Pune—DRDO)

ERDL has developed a process for producing celluloid coated/rayon cambric sheet. It is used in Defence for the manufacture of secondary containers for mortar ammunition. The product may also find its application in other defence stores as a substitute for celluloid. Defence Department is anticipated to consume nearly 1.5 lakh sq. metres of the product per year. Suggested optimum plant capacity 250 to 300 sq. m per day. CC Rs.10 lakhs.

1000:35. Jacquard board

(RRL, Jorhat—CSIR)

Jacquard boards are extensively used in textile industry for weaving purposes. The process for making jacquard board is particularly advantageous for existing board mills for product diversification and can be adopted without any additional investment on plant and machinery. The plant and machinery cost for one TPD capacity plant has been estimated to be Rs.6 lakhs.

1000:36. Modification of natural and synthetic fibres through discharge technique

(Sri Ram Institute for Industrial Research, Delhi)

At present certain chemicals are added to textile fibres to reduce fly waste, lower the twist needed to develop maximum yarn strength, improved spinnability and/yarn tensile strength. However, the effects of these chemicals are temporary and is lost when cotton in the fabric is wet finished. Treating fibres with corona results in improvement of all the above mentioned properties. Carona treatment permanently modifies the fibre surface, commonly called mill scale, mill scales and is effected upto depth of 100° A.

1000:37. Non cyanide industrial zinc plating bath

(Central College, Bangalore University)

Non-cyanide acid zinc plating baths are gaining importance over alkaline cyanide baths due to the problems of toxicity and industrial waste disposal.

A non-cyanide acid zinc plating bath has been developed for vat plating with dextrine as the primary brightener and thiamine hydrochloride as secondary brightener. The bath could also be used for barrel plating of small components with a slight alteration in bath composition. The insensitivity of the brightness of the deposit to the operative parameters, good deposition rate without expensive effluent treatment should make the process attractive for commercial use.

Following processes are also available for licensing:

1. **Grinding/lapping compounds from palm oil sludge**
   (RRL, Bhubaneswar—CSIR)
2. **Hopcalite catalyst**
   (DMSRDE, Kanpur—DRDO)
3. **Sensitive zinc oxide electrostatic photographic paper**
   (CECRI, Karaikudi—CSIR)
4. **Paper slate**
   (RRL, Jorhat—CSIR)
5. **Dust mask**
   (DMSRDE, Kanpur—DRDO)

*6. **Carbon remover**
(DMSRDE, Kanpur—DRDO)

*7. **Auto-rust & scale inhibitor-70**
(DMSRDE, Kanpur—DRDO)

8. **RF induction heater 1.2 kW & 5 kW**
   (CEERI, Pilani—CSIR)
9. **Dry shampoo**
   (DRDE, Gwalior—DRDO)

For additional information please contact:

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'Anusandhan Vikas'
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